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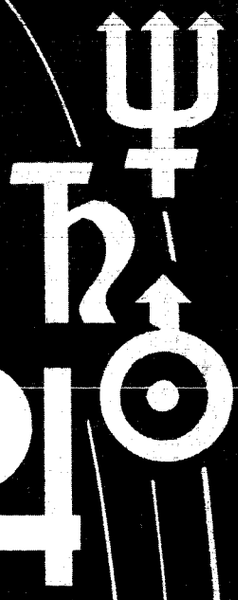


Outer Pla[illegible] Entry Probe System Study

Final Report

Volume III Appendixes

August 1972

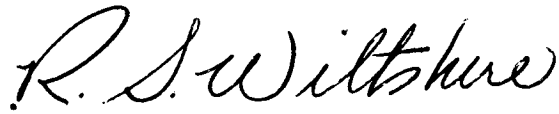
MARTIN MARIETTA

JPL Contract 953311

Volume III | Appendixes | August 1972

OUTER PLANET ENTRY PROBE SYSTEM STUDY

FINAL REPORT



R. S. Wiltshire
Program Manager

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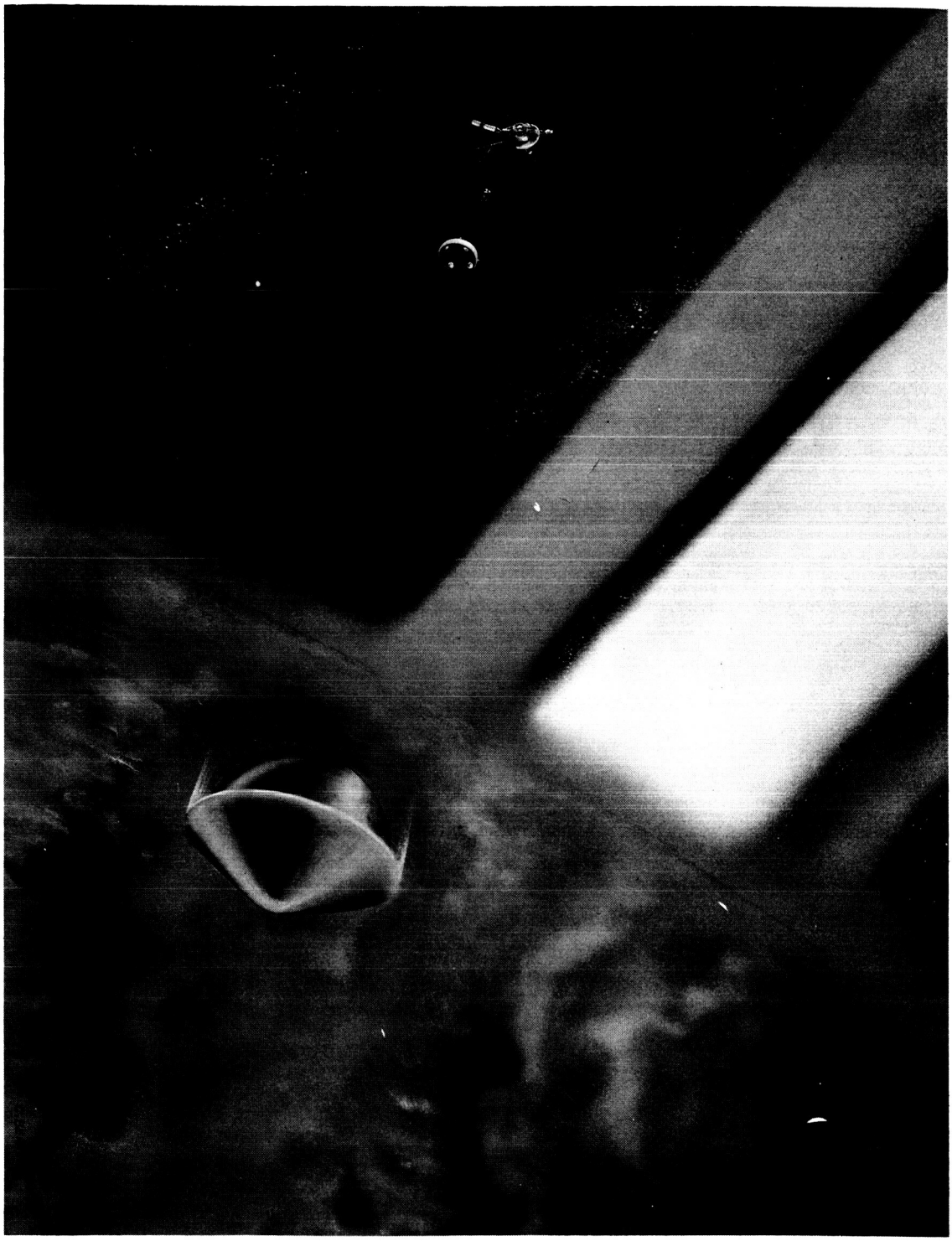

Survivable Saturn Atmosphere Probe

FOREWORD

This final report has been prepared in accordance with requirements of Contract JPL-953311 to present data and conclusions from a six-month study for the Jet Propulsion Laboratory by Martin Marietta Aerospace, Denver Division. The report is divided into the following volumes:

Volume I - Summary

Volume II - Supporting Technical Studies

Volume III - Appendixes

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CONTENTS

APPENDIX A

MICROWAVE LOSSES IN THE ATMOSPHERES OF JUPITER, SATURN, AND URANUS

R. J. Richardson
and
R. E. Compton, Jr.

June 6, 1972

MICROWAVE LOSSES IN THE ATMOSPHERE OF JUPITER, SATURN, AND URANUS

The techniques used to calculate microwave losses in the planet atmospheres are essentially those used on the original Jupiter atmospheric study as described in the final report of that contract (Ref 1). A long list of references given in this report will not be repeated here (Ref 1, p IV-136). Some changes have been made in the methods of calculating cloud absorption, which are outlined in this appendix.

The atmospheres of the three planets are all quite similar, being composed primarily of hydrogen (H_2) and helium (He) with trace amounts of other gasses. The principal sources of absorption in the atmospheres are (1) pressure broadening of absorption lines in the polarizable gasses, ammonia (NH_3) and water (H_2O) and (2) absorption in the clouds. Total attenuation increases as the aspect angle is moved away from zenith. Absorption is computed as a function of elevation, z, measured from an altitude where the pressure is one bar; the look vector aspect angle measured from zenith, ψ; and the transmission frequency, f. A second source of signal loss is defocusing loss caused by ray-bending in the dense atmosphere. This loss is computed as a function of z and ψ and is independent of frequency. The atmosphere models are derived from the contractual documents supplied by JPL. Both the "nominal" and the "cool/dense" atmospheres were worked for Jupiter, while only the "nominal" atmospheres were analyzed for the other two planets.

A. ABSORPTION LOSSES

Ammonia (NH_3) has a large group of absorption lines (the inversion spectrum) centered around 25 GHz. These lines are very narrow at low pressure and are broadened by increasing pressure, merging into a single line for pressures greater than one atm. Although 25 GHz is remote from the frequency band of interest for telecommunications (around 1 to 2 GHz), line broadening caused by the very high pressures encountered in the mission is sufficient to cause substantial attenuation even at these relatively low frequencies. It was found that even the rotational spectrum of NH_3, extending upward from 600 GHz, results in an absorption at these pressures that is not completely negligible. Similarly, water (H_2O) has a spectrum of absorption lines extending upward from 22 GHz with pressure broadening causing the effects to be perceptible at the much lower frequencies of interest for this mission.

1. Ammonia Absorption

The Ben-Reuven (Ref 2) line shape was used for absorption caused by gaseous NH_3. The Ben-Reuven shape factor is given by

$$SF = \frac{2(\gamma - \beta)f^2 + 2(\gamma + \beta)\left(\nu_o^2 + \gamma^2 - \beta^2\right)}{\left(f^2 - \nu_o^2 - \gamma^2 + \beta^2\right)^2 + (2f\gamma)^2} \qquad [A-1]$$

ν_o is the line resonant frequency, 25 GHz. For this application, $f << \nu_o$. β and γ are proportional to density. This gives

$$SF \cong \frac{2(\gamma + \beta)}{\nu_o^2 + \gamma^2 - \beta^2} \qquad [A-2]$$

$$\cong \frac{2(\gamma + \beta)}{\nu_o^2} \text{ (low pressures)} \qquad [A-3]$$

$$\cong \frac{2}{\gamma - \beta} \text{ (high pressures)} \qquad [A-4]$$

and β, γ, ν_o, and f are in GHz.

Computation of the absorption coefficient, $\alpha(z)$, was done using Equation [A-5]. This was then integrated over the atmosphere profile to give the total zenith absorption. $\alpha(z)$ and $\int_{z_o}^{\infty} \alpha(z)dz$ are converted to dB per km and dB by the factor $10 \log_{10}(e) = 4.35$. The absorption coefficient is computed from

$$\alpha(z) = k_1 f^2 A_N SF(z) \left[\frac{P(z)}{T(z)^2}\right] km^{-1} \qquad [A-5]$$

where A_N is the abundance of ammonia, P is the pressure in atm, T is the temperature in °K, SF(z) is defined by Equations [A-2] through [A-4], f is the applied frequency in GHz, and k_1 is matched to experimental data. Since γ and β are proportional to density, which increases with depth in the atmosphere, we can write

$$\gamma(z) = k_2 \frac{P(z)}{T(z)} \qquad [A-6]$$

$$\beta(z) = k_3 \frac{P(z)}{T(z)} \qquad [A-7]$$

where k_2 and k_3 are matched to experimental data and are a function of the foreign gasses, H_2 and H_e, as well as the absorbing gas, ammonia.

Values used for k_1, k_2, and k_3 are

$$k_1 = 2.028 \times 10^6 \qquad [A-8]$$

$$k_2 = 462.8 \left(A_{H_2} + 0.24\ A_{He}\right) \qquad [A-9]$$

$$k_3 = 231.4 \left(A_{H_2} + 0.24\ A_{He}\right) \qquad [A-10]$$

where A_{H_2} and A_{He} are abundances of H_2 and He, respectively.

The contribution caused by the rotational spectrum of ammonia is quite small, less than 5% of the inversion spectrum contribution at high pressures in a nominal atmosphere and less at low pressures. However, it was included in the computation. It follows the relationship

$$\alpha_{rot} = 71.1 A_N\ f^2 \left(A_{H_2} + 0.267\ A_{He}\right) \frac{P(z)^2}{T(z)^{2.5}} \quad km^{-1} \qquad [A-11]$$

2. Water Vapor

Based on measured data, it was decided that the approach used by Ho (Ref 3), modified to match the H_2 - He foreign gasses on the outer planets, will give more accurate results at high pressure than the line-broadening approach. This gives the relationship

$$\alpha_{H_2O} = 7.35 \times 10^6 \left(1023\ A_{H_2} + 870\ A_{He}\right) A_{H_2O}\ f^2 \frac{P(z)^2}{T(z)^5} \qquad [A-12]$$

where A_{H_2O} is the water vapor abundance. Water contribution to the absorption is less than 10% of the total in all of the model atmospheres for which absorption was computed.

3. Clouds

The only clouds that give significant absorption are the liquid droplet water-ammonia (H_2O - NH_3) solution clouds. Calculation of these losses is complicated by the electrical conductivity of the solution, which is a function of solution strength, and varies with elevation within the cloud. In order to determine the effect of these clouds, it is necessary to determine the dielectric constant and electrical conductivity as a function of temperature and solution strength. Conductivity, σ (ohm^{-1} m^{-1}), as a function of solution strength, at 291°K is shown in Figure A-1 (Ref 4). Conductivity varies with temperature in °K, with respect to the conductivity at 291°K as shown in Figure A-1, approximately as

$$\sigma(T) \approx \sigma(291)\left(\frac{T}{291}\right)^{6.2} \qquad [A-13]$$

The NH_3 and H_2O solution is characterized as weak electrolytes with low conductivity. The complex dielectric constant, ε_j, is taken from Reference 5 and defined by

$$\varepsilon_j = \varepsilon_r + j\varepsilon_i \qquad [A-14]$$

where

$$\varepsilon_r = \frac{\varepsilon_\infty + \varepsilon_o\left(\lambda_c/\lambda\right)^2}{1 + \left(\lambda_c/\lambda^{\,2}\right)} \qquad [A-15]$$

$$\varepsilon_\infty \cong 81.1\left(\frac{291}{T}\right)^{1.4}, \text{ and } \varepsilon_o \cong 5 \qquad [A-16]$$

over the temperature range of interest for water. The RF wavelength, λ, is given by

$$\lambda = \frac{30}{f} \text{ cm} \qquad [A-17]$$

for the frequency, f, in GHz.

The critical wavelength, λ_c, is approximated by

$$\lambda_c \cong 3.34\left(\frac{273}{T}\right)^{7.2} \text{ cm} \qquad [A-18]$$

with T in °K.

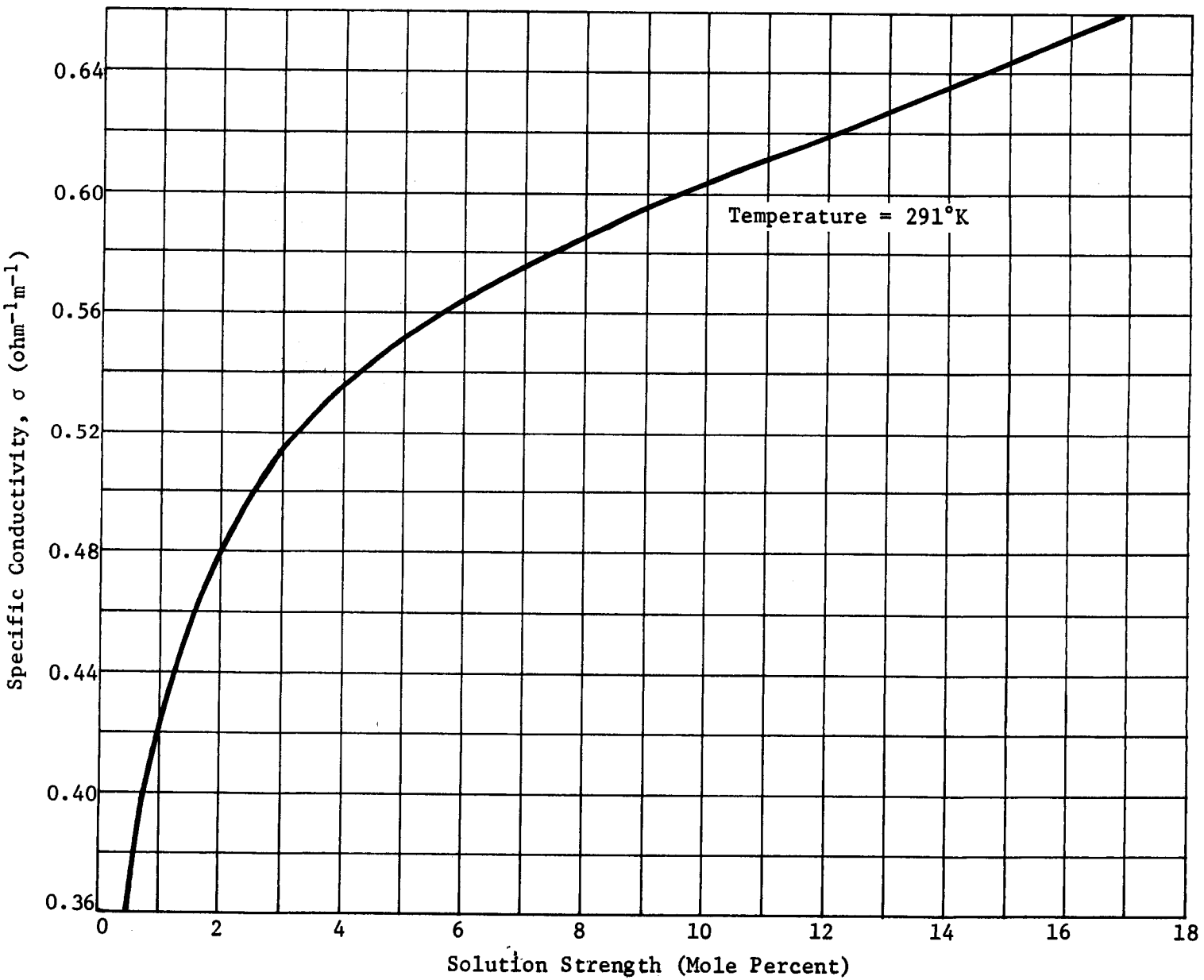

Figure A-1 Specific Conductivity of NH_3 - H_2O Solution Clouds

The imaginary portion of the dielectric constant is given by

$$\varepsilon_i = \frac{\left(\varepsilon_\infty - \varepsilon_o\right)\left(\lambda_c/\lambda\right)}{1 + \left(\lambda_c/\lambda\right)^2} + 60\,\lambda\sigma. \qquad \text{[A-19]}$$

The cloud absorption coefficient α_c is given by

$$\alpha_c = BM \text{ dB/km} \qquad \text{[A-20]}$$

where M is the cloud density in g/m^3 and B is ideally given by

$$B = 0.4343\,\frac{6\pi}{\lambda}\,\mathrm{Im}\left(-\frac{\varepsilon_j - 1}{\varepsilon_j + 2}\right). \qquad \text{[A-21]}$$

Over the frequency range of interest, this simplifies to

$$B \cong \frac{24.53\,\varepsilon_i}{\left[\left(\varepsilon_r + 2\right)^2 + \varepsilon_i^{\,2}\right]\lambda} \qquad \text{[A-22]}$$

4. Absorption Results

The equations cited above were programmed to compute gaseous absorption and the integral of absorption versus depth of penetration into the atmosphere. The model atmosphere data were placed into the computation using a data deck of P, T, and z with 5-km intervals on z. Abundances used deep in the atmosphere were taken from the contract model atmospheres. Variations in NH_3 and H_2O abundances in and above the clouds were computed for one case. It was found that these abundances dropped so rapidly in and above the clouds that adequate accuracy for absorption computations is given by

$$A'_{NH_3} = \begin{cases} A_{NH_3} \text{ when } T(z) \geq T_{sat} \\ 0 \text{ when } T(z) < T_{sat} \end{cases} \qquad \text{[A-23]}$$

where

A'_{NH_3} = ammonia abundance

z = elevation from pressure of one bar, km

T = temperature, °K

T_{sat} = saturation temperature in the given model, °K

A similar expression was used for water.

A program was developed to compute cloud mass, cloud state (liquid or solid), and cloud composition (solution strength for the H_2O and NH_3 solution cloud) as a function of elevation in these atmospheres. The results were used in a separate program to compute cloud absorption as a function of frequency using the formulas given previously. The results, gaseous absorption plus cloud absorption, were then combined. Figures A-2 through A-5 give the results for Jupiter cool/dense, Jupiter nominal, Saturn nominal, and Uranus nominal. Jupiter nominal and Saturn nominal do not have solution clouds, so absorption scales as f^2 in these models. Jupiter cool and Uranus nominal do have solution clouds, so scaling is not exactly as f^2, though it is very nearly so.

B. REFRACTION EFFECTS

1. Defocusing Loss

The technique used to compute defocusing loss has been described in detail in Reference 6 and is summarized here.

First, the refractivity profile was computed, using the equation

$$N'(z) = \frac{P(z)}{T(z)} \left(37180\ A_{H_2} + 9550\ A_{He}\right) \qquad [A-24]$$

where the coefficients of A_{H_2} and A_{He} are matched to measured values at P = 1 atm and T = 273°K. These are N'_{H_2} = 136.1 and N'_{He} = 35.0 from the International Critical Tables.

$N'(z)$ is defined by $n = 1.0 + 10^{-6}\ N'(z)$, where n is the index of refraction. In subsequent formulas, we use $N(z) = 10^{-6}\ N'(z)$.

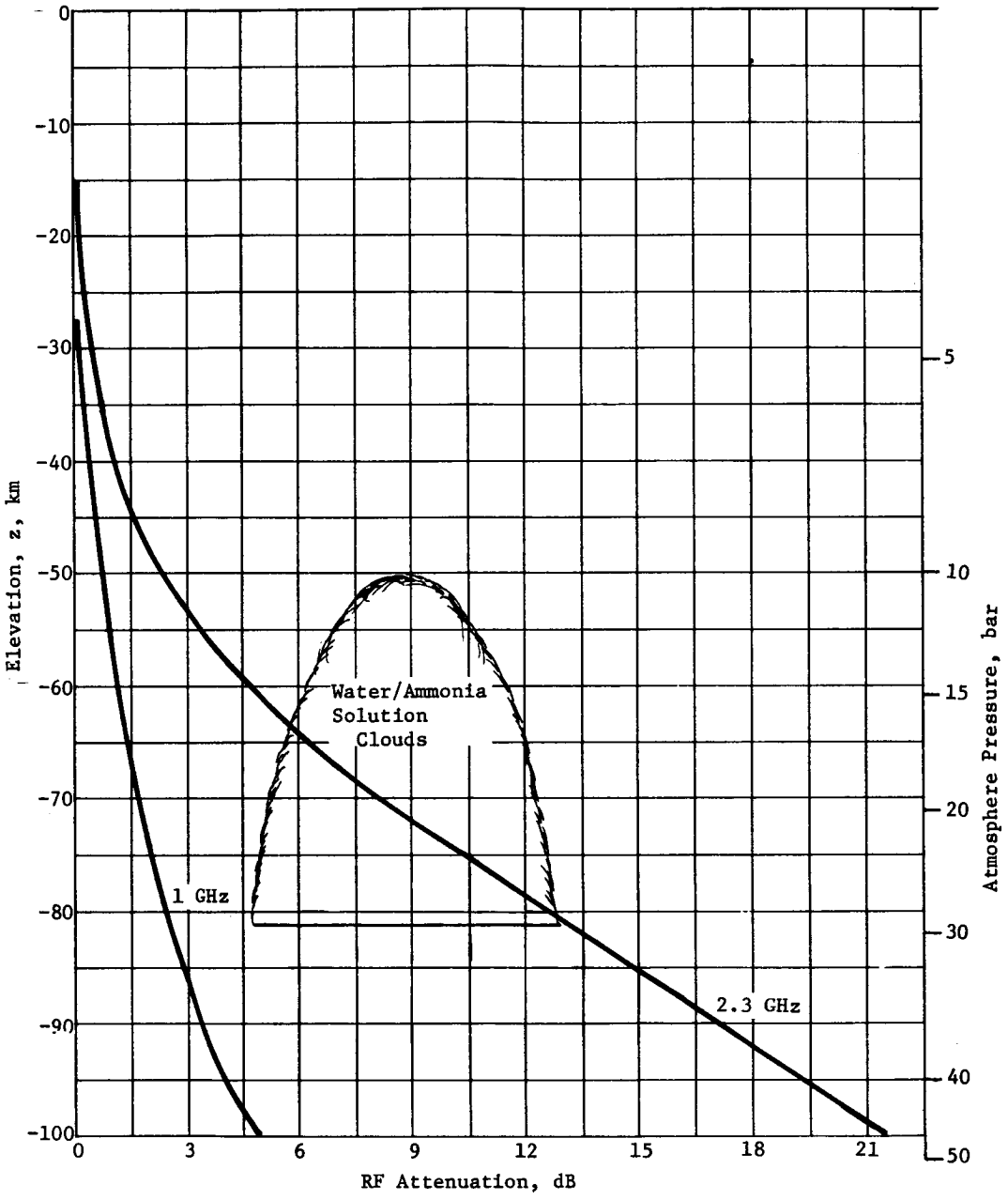

Figure A-2 Zenith Absorption for the Jupiter Cool/Dense Atmosphere

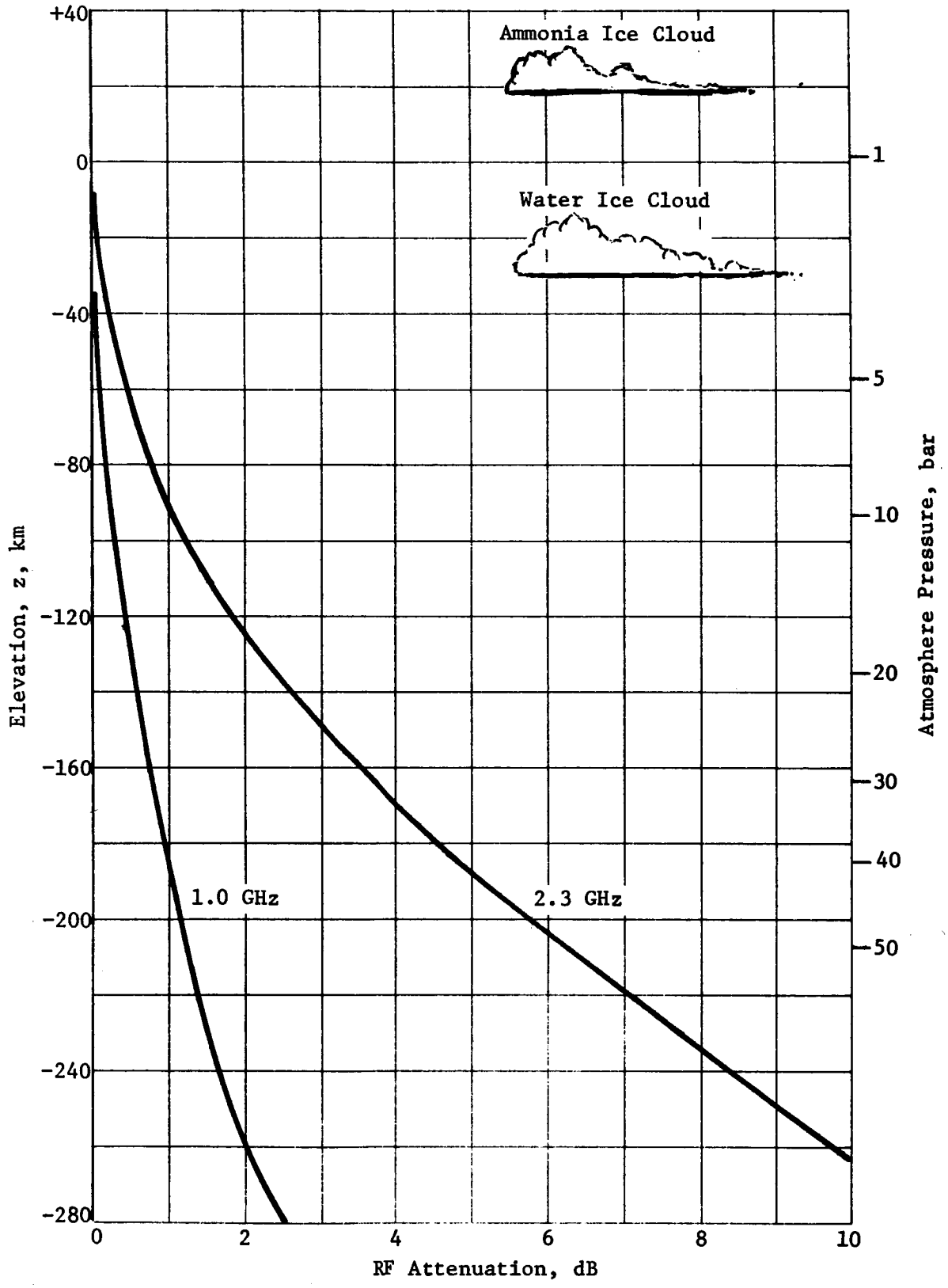

Figure A-3 Zenith Absorption for the Jupiter Nominal Atmosphere

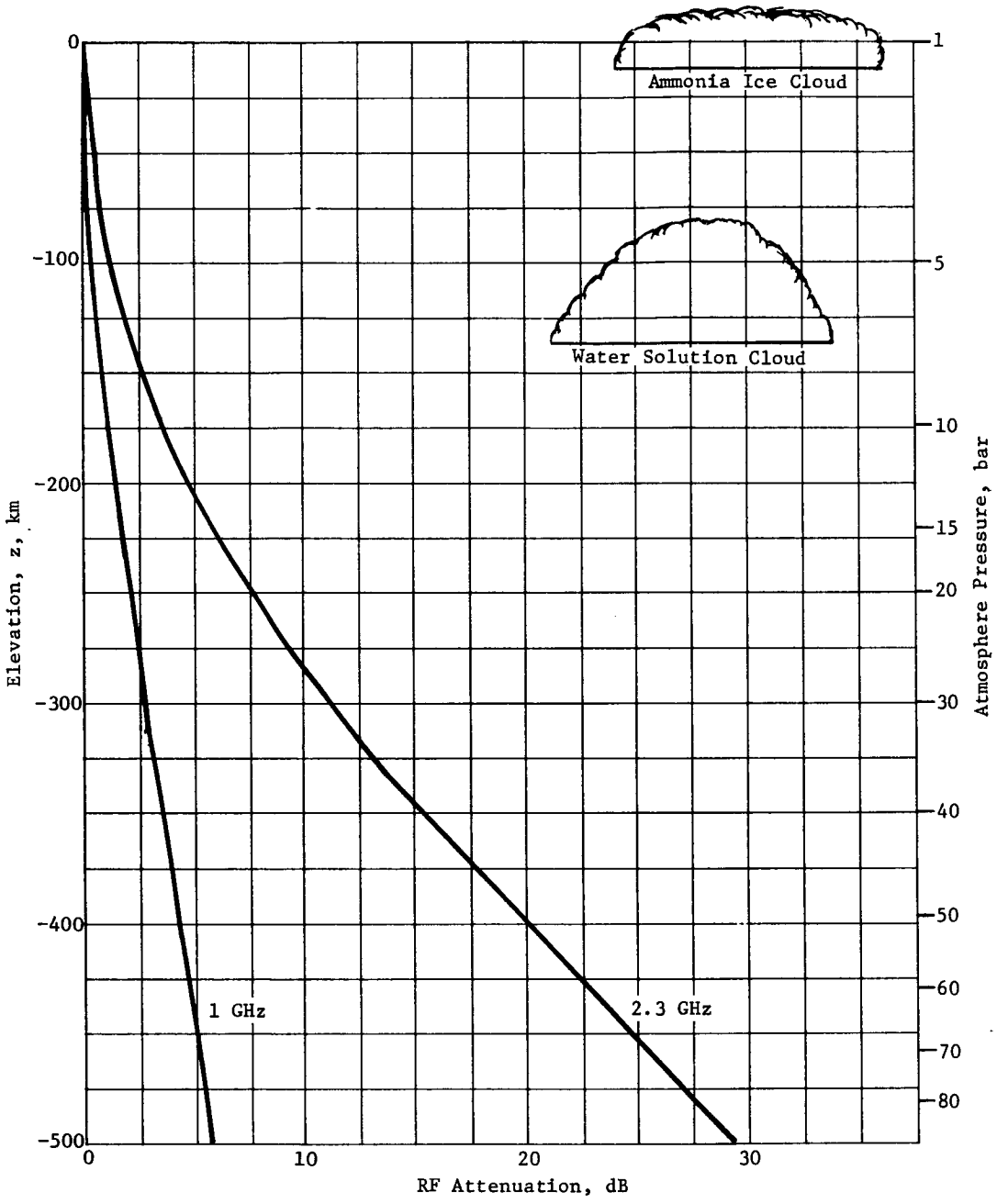

Figure A-4 Zenith Absorption for the Saturn Nominal Atmosphere

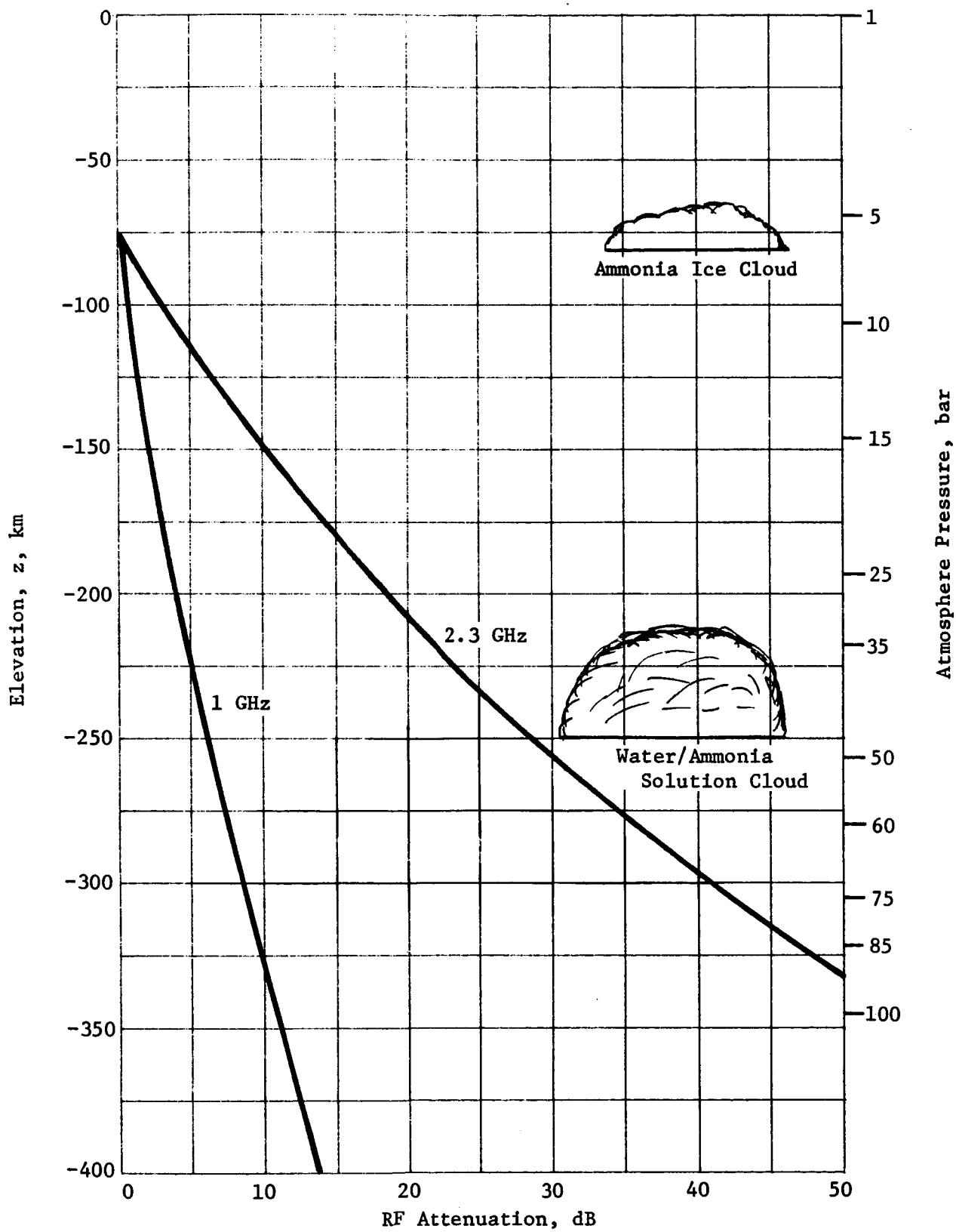

Figure A-5 Zenith Attenuation for the Uranus Nominal Atmosphere

The N-profile is then approximated by an exponential

$$N(z) = N(z_o) \exp\left[-\beta\,(z - z_o)\right] \qquad \text{[A-25]}$$

by selecting β that best matches the profile starting from the selected z_o. β^{-1} is the scale height.

Ray bending (or pointing error, E) for an exponential atmosphere can be computed from the refraction integral. The ray launch angle, θ, is measured from zenith.

The pointing error as a function of the ray angle is given by

$$E(\theta) = N_o\, n_o \sin\theta \int_o^\infty \frac{e^{-x}\,dx}{\left(1 + N_o\, e^{-x}\right)\sqrt{\left(1 + \frac{x}{\beta r_s}\right)^2 \left(1 + N_o\, e^{-x}\right)^2 - n_o^2 \sin^2\theta}} \,. \qquad \text{[A-26]}$$

The defocusing loss is calculated from

$$L_d(\theta) = \frac{1}{1 + \frac{dE}{d\theta}} \,. \qquad \text{[A-27]}$$

It is independent of frequency, but is a function of z_o and θ. It is more convenient to plot L_d vs $\psi = \theta + E(\theta)$, the angle at which the ray emerges from the atmosphere. Results for the four atmospheres are shown in Figure A-6 through A-9 with the ray angles defined in Figure A-6.

2. Absorption Loss

For small departures from zenith, attenuation due to atmospheric absorption, $L_a(\theta)$, increases as $\sec\theta \cong \sec\psi$. For larger ψ, ray-bending effects must be considered. $L_a(\theta)$ is bounded by

$$L_a(0) \sec\theta \text{ (lower bound)}$$
$$L_a(0) \sec\psi \text{ (upper bound).} \qquad \text{[A-28]}$$

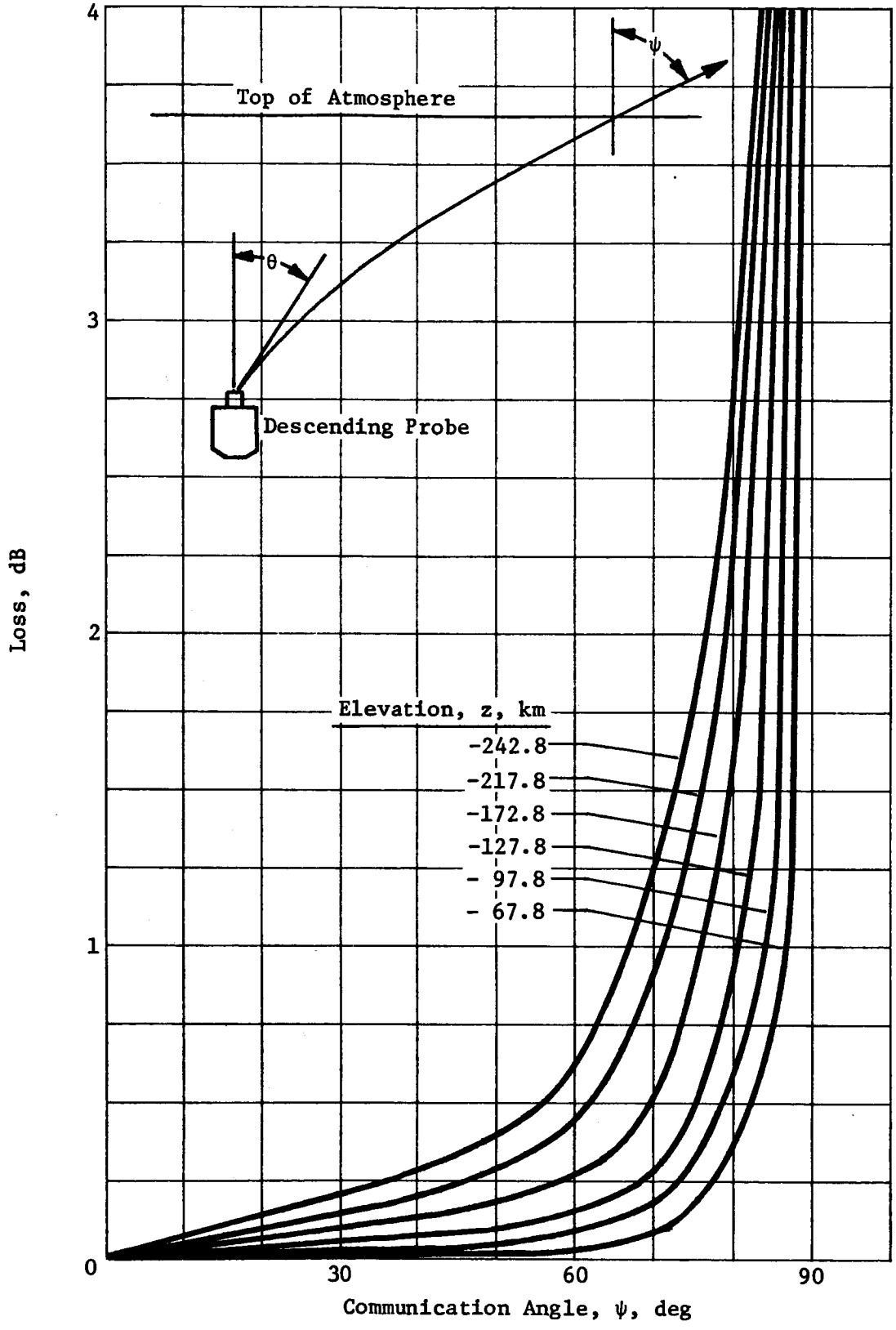

Figure A-6 Defocusing Loss for the Jupiter Cool/Dense Atmosphere

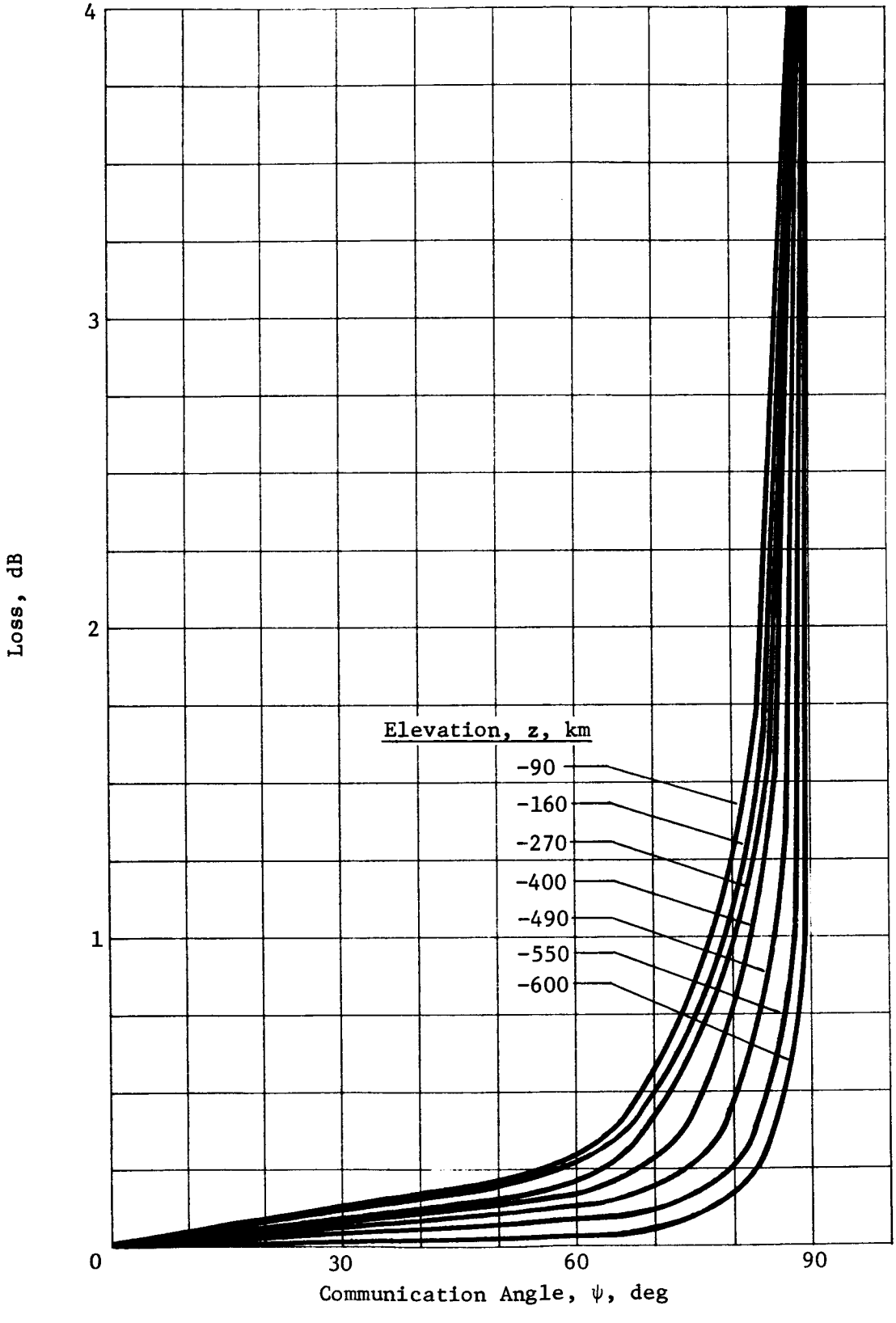

Figure A-7 Defocusing Loss for the Jupiter Nominal Atmosphere

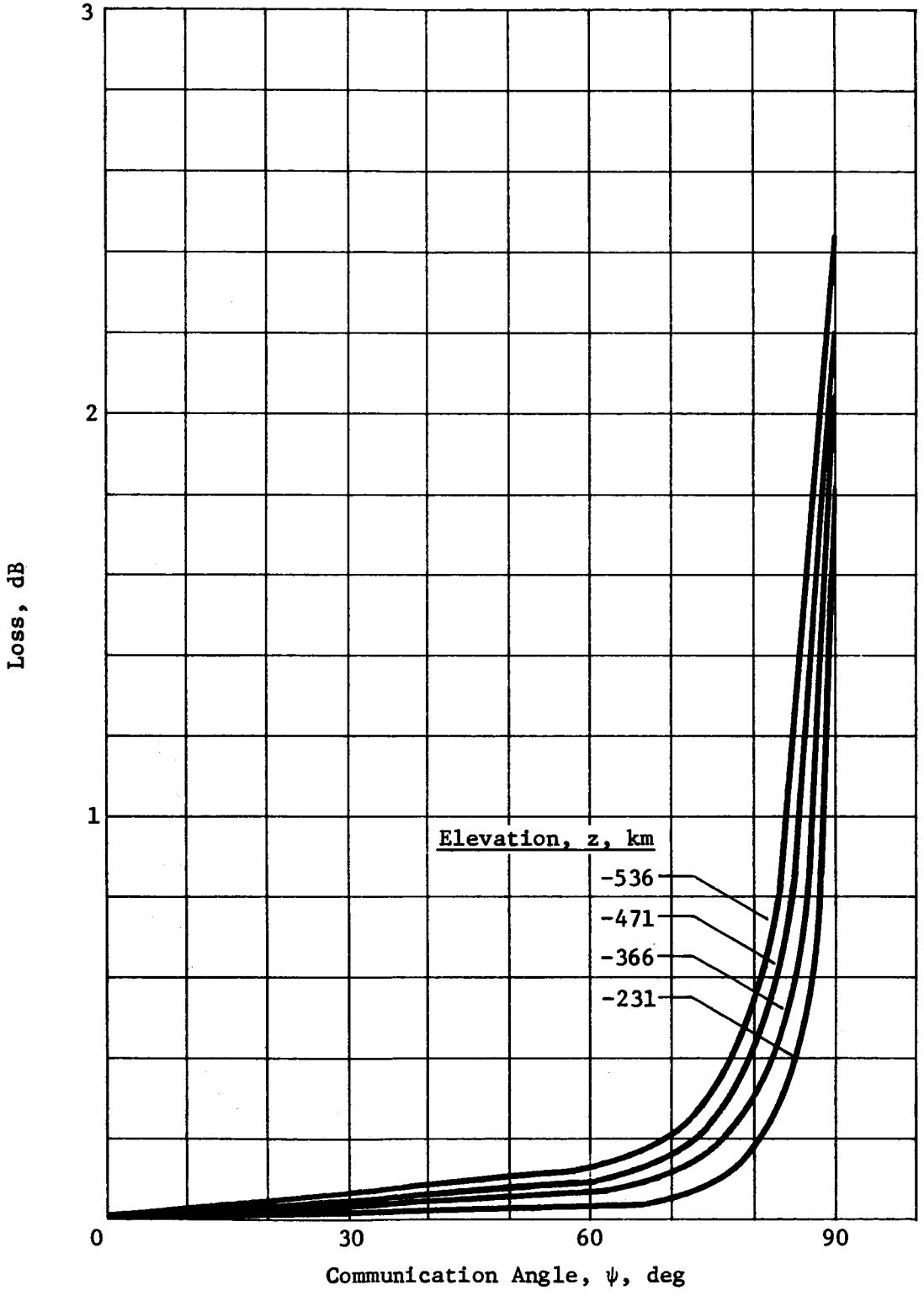

Figure A-8 Defocusing Loss for the Saturn Nominal Atmosphere

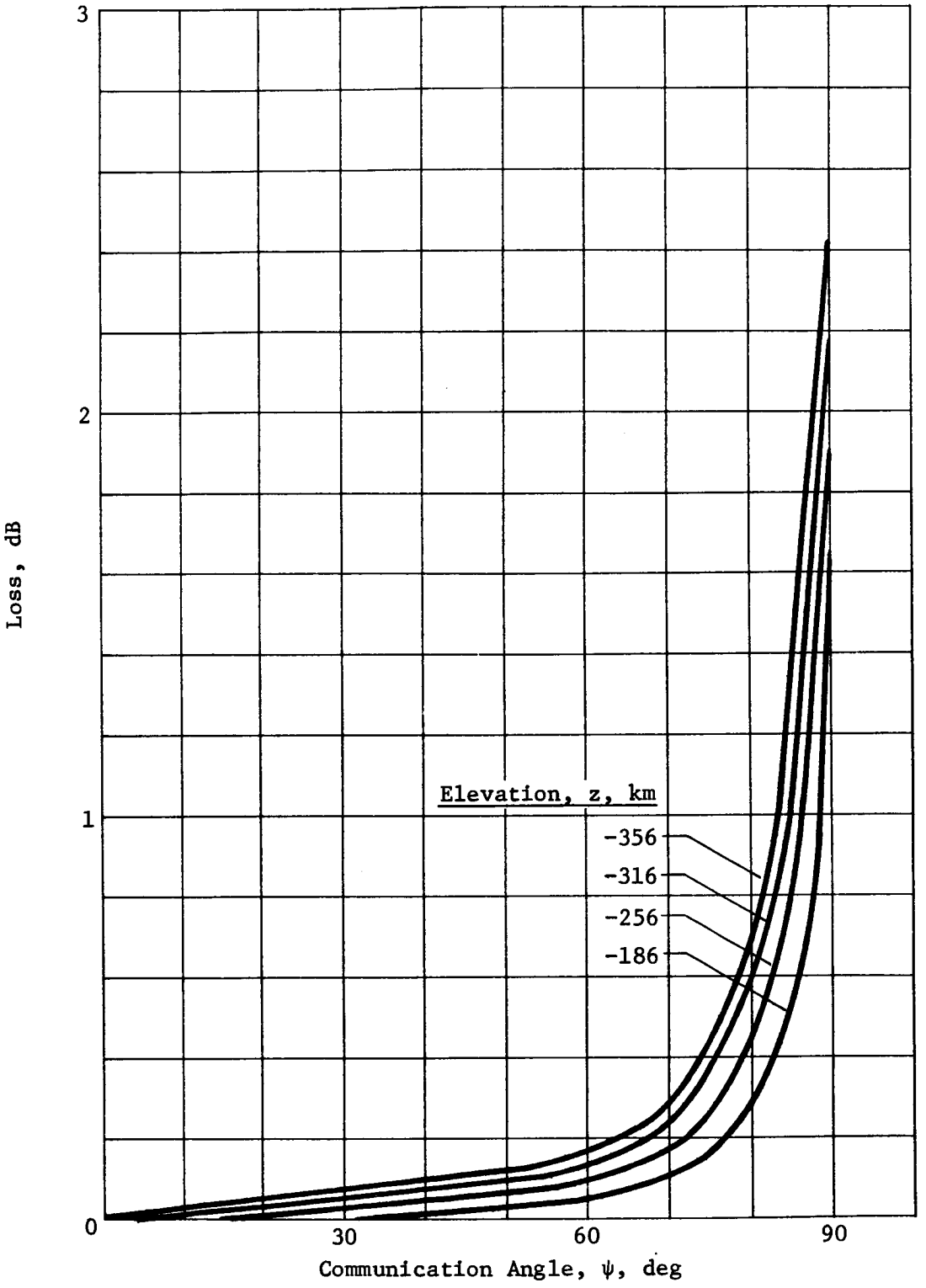

Figure A-9 Defocusing Loss for the Uranus Nominal Atmosphere

A value midway between these bounds gives adequate accuracy for $L_a(\theta)$. As with L_d, it is more useful to plot L_a as a function of ψ. A normalized absorption loss, L_{an}, is plotted for various depths, z, in all four model atmospheres in Figures A-10 through A-13. The plots are normalized to a zenith absorption of 1 dB. To use them, the appropriate value of $L_{an}(\psi, z)$, taken from these curves, must be multiplied by the actual value of zenith absorption, $L_a(0, z, f)$, taken or scaled from Figures A-2 through A-5. It is clear from these curves that the sec ψ approximation is quite good out to 60 deg off zenith.

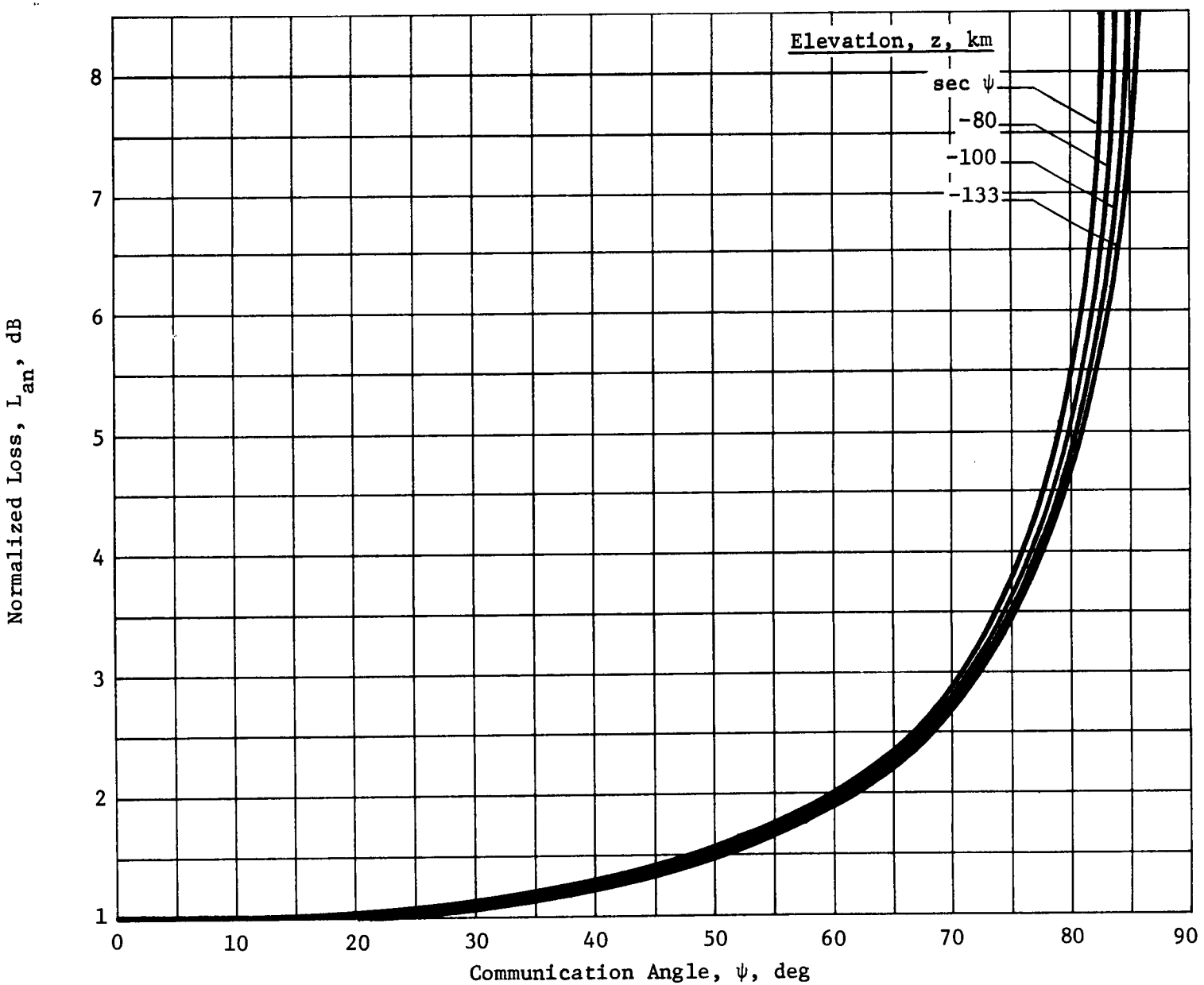

Figure A-10 Normalized Absorption Loss for the Jupiter Cool/Dense Atmosphere

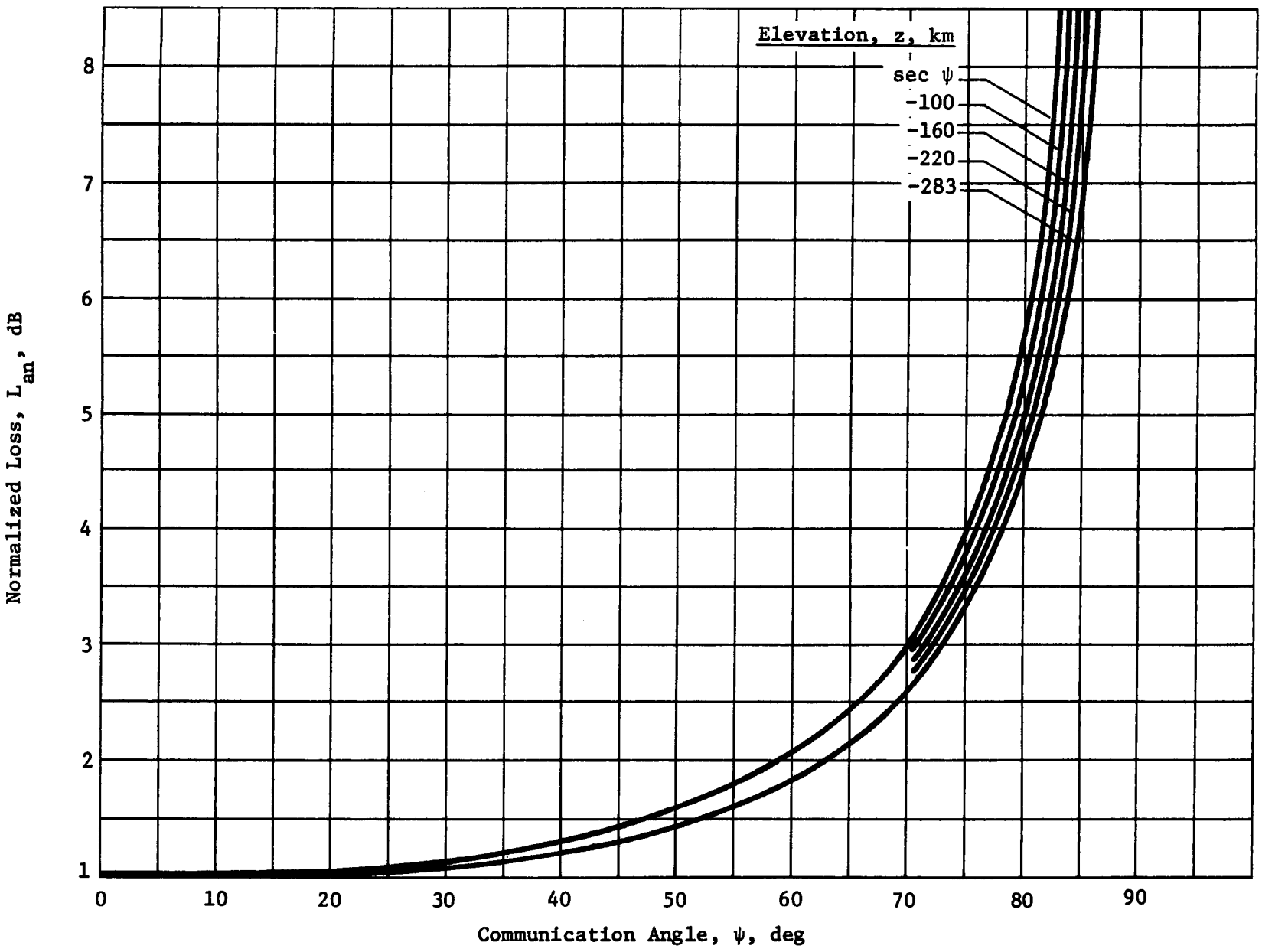

Figure A-11 Normalized Absorption Loss for the Jupiter Nominal Atmosphere

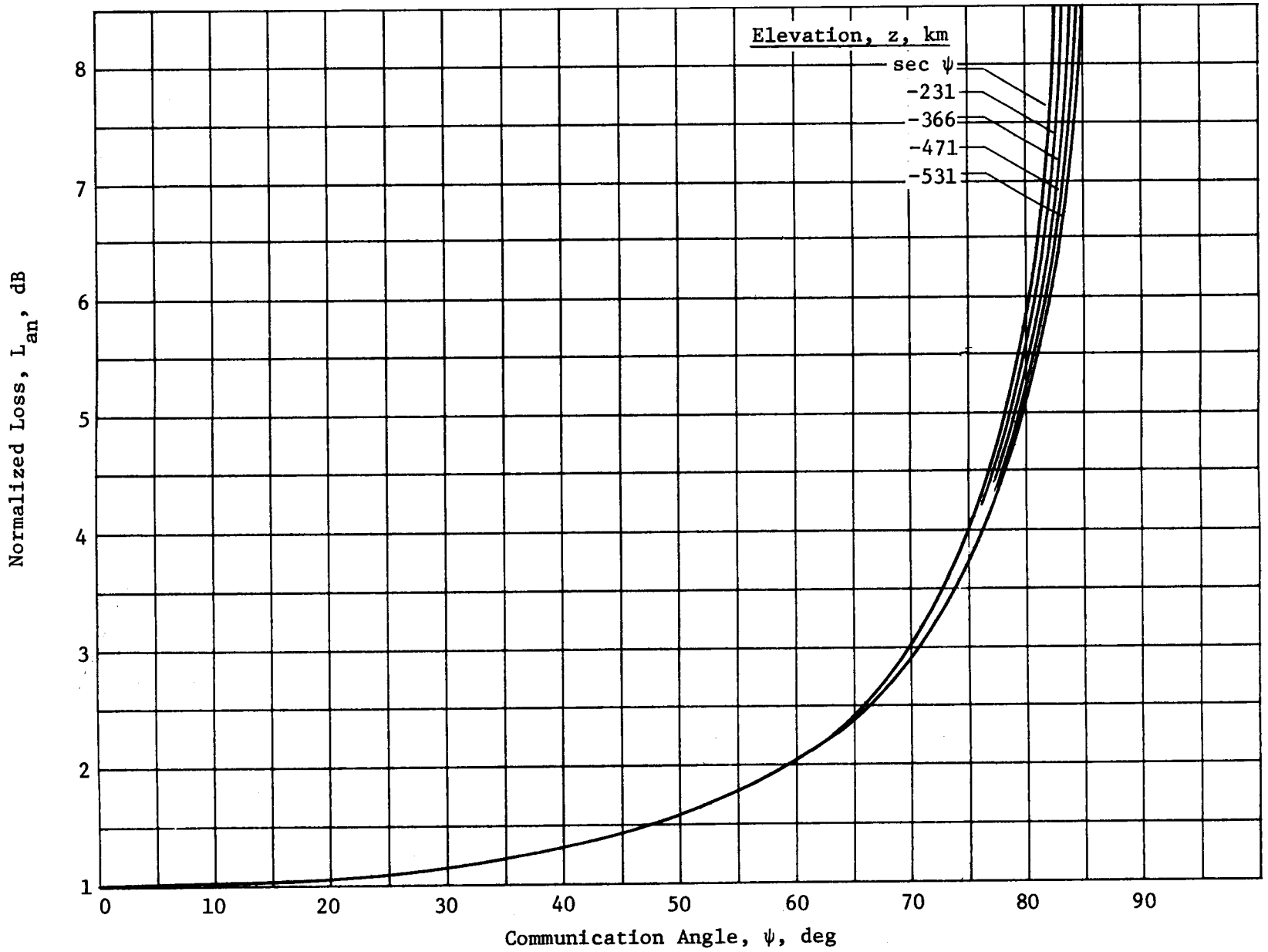

Figure A-12 Normalized Absorption Loss for the Saturn Nominal Atmosphere

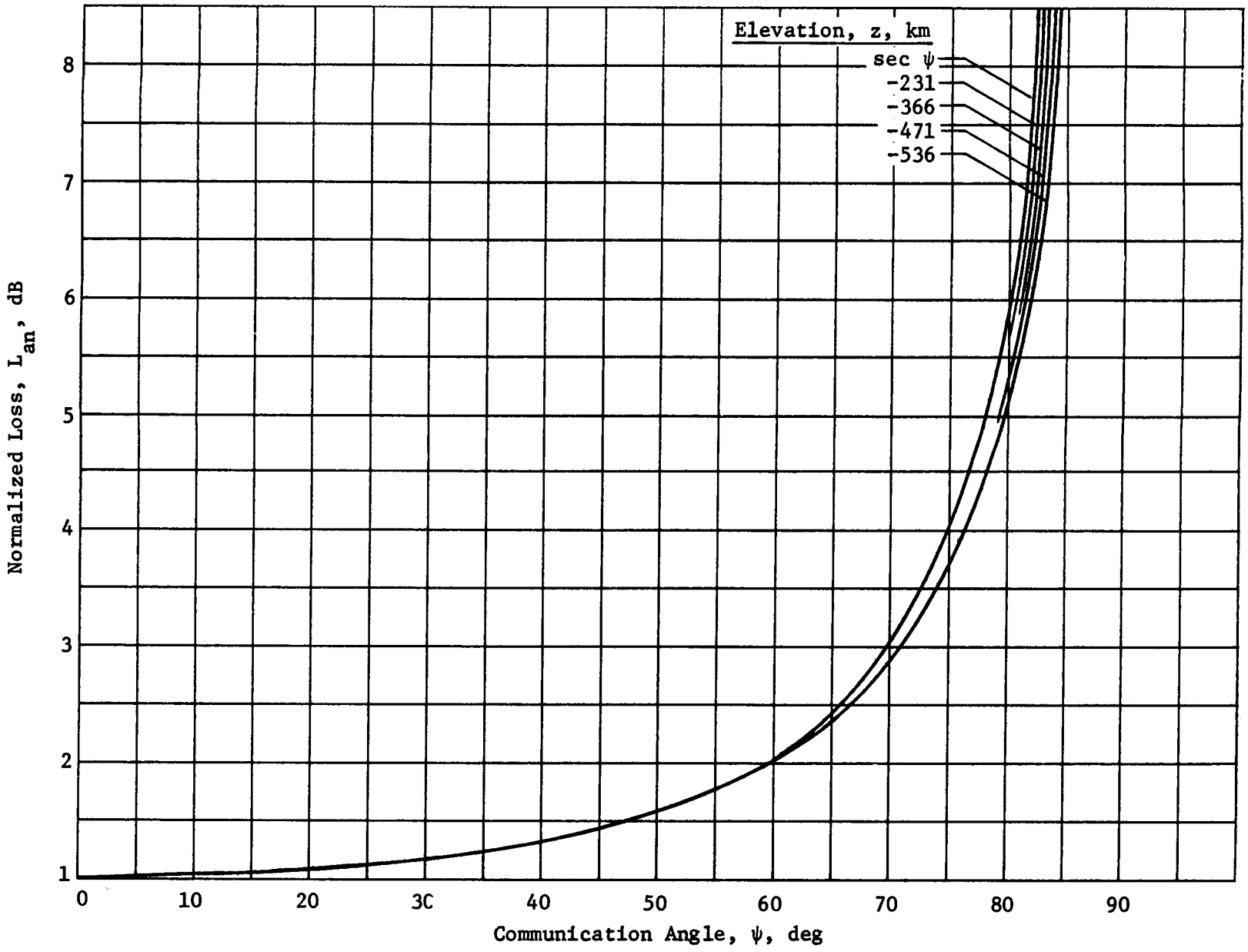

Figure A-13 Normalized Absorption Loss for the Uranus Nominal Atmosphere

TRAJECTORY PROGRAM INPUTS

The curves of Figures A-2 through A-13 were not generally used directly in the link calculations. These calculations have been programmed and incorporated as a subroutine (RATMA) into the trajectory program. Empirical curves were matched to these data, giving combined absorption and defocusing loss in a readily computable form as a function of ψ, z, and f. Atmosphere absorption is calculated for zenith as a function of frequency and elevation. Next, absorption is calculated at the probe aspect angle, ψ. Defocusing loss is also calculated at ψ and the total atmosphere attenuation is the sum of absorption and defocusing losses at ψ. Typical missions are designed with small probe aspect angles (<20°) at atmosphere entry and decreasing angle with descent. Therefore, the zenith attenuation is approximately the total attenuation because $L_d(\psi)$ is quite small and $L_a(\psi)$ differs little from $L_a(0)$. In general,

$$L_A(\psi, z, f) = L_a(\psi, z, f) + L_d(\psi, z) \qquad [A-29]$$

where

L_A = total atmosphere attenuation including absorption and defocusing loss, dB

L_a = atmosphere absorption, dB

L_d = defocusing loss, dB.

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APPENDIX B

MICROWAVE FREQUENCY SELECTION

R. E. Compton, Jr.

June 7, 1972

MICROWAVE FREQUENCY SELECTION

There are three factors that contribute heavily to the selection of an optimum RF frequency for the probe-to-spacecraft link. These are the system noise temperature, the atmospheric attenuation, and the space loss which is a function of range and frequency. Lower limit bounds are determined by the physical size of the probe antenna for a given wavelength. In general, the receiver system noise temperature increases, the atmospheric attenuation decreases, and the space loss decreases as the frequency is decreased. In addition, for a mission designed with decreasing range and probe aspect angle versus descent, the space loss will also decrease versus time. The probe antenna gain also increases during descent because of a decrease in the probe aspect angle towards the maximum antenna beam gain point.

A. SPACECRAFT ANTENNA TEMPERATURE FOR A JOVIAN MISSION

The noise temperature of the probe relay antenna on the spacecraft is determined by investigating the sources and magnitudes of decimetric (UHF) radiation from Jupiter. There are two sources of RF noise: thermal radiation from the disk and nonthermal UHF radiation from the Jovian magnetosphere. The spacecraft antenna is directed towards the planet disk while the probe is transmitting descent data and encounters the greatest amount of UHF radiation. The antenna temperature used in the previous Jupiter study (Ref 1) was taken from the microwave brightness temperature curve (Ref 2, Fig. 2-2). This curve is depicted in Figure B-1 for reference. The curve attributed all the measured temperature to the planet disk, which results in a higher radiative flux than if the magnetosphere volume had also been considered. At about 3 cm, the equivalent blackbody disk temperature begins to increase rapidly because of contributions from nonthermal sources, as seen in the 1967 curve of Figure B-1. This effect is also evident in the flux density versus wavelength curve which indicates a slowly decreasing trend departing from that expected for blackbody emissions at a fixed temperature.

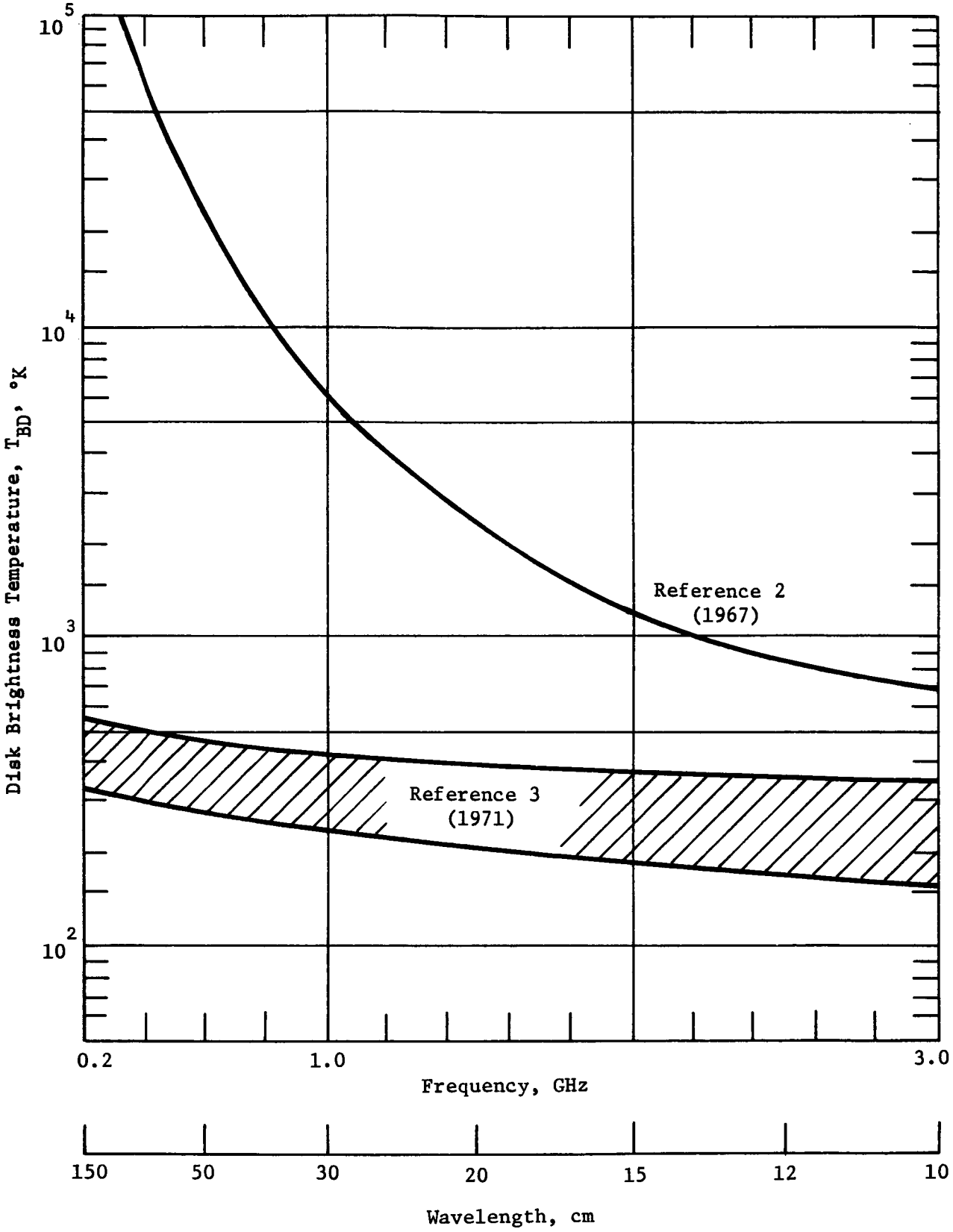


Figure B-1 Jovian Disk Brightness Temperature

It was suggested in 1967 (Ref 2, pp 56, 60-62) that the irregular (decimetric) emission apparently originates in the Jovian radiation belts. Various investigations have shown that the intensity of decimetric radiation appears to be constant over long periods of time and has a strong linearly polarized component with a source dimension several times the size of the visible planet disk. It is generally accepted that the radiation is caused by electrons trapped in the magnetic field of Jupiter, forming a Van Allen belt similar to that about Earth. Synchrotron (relativistic) radiation is the mechanism that explains these observed radiation characteristics. Cyclatron radiation is rejected since it requires the presence of an abnormally strong magnetic field.

The latest available information (Ref 3) provides additional knowledge on the radio radiation environment, particularly the Jovian magnetosphere. The environmental design criteria separate the brightness temperature into the two aforementioned sources and provide a model for synchrotron radiation and a disk brightness temperature curve that is lower than the 1967 data.

Kellermann (Ref 4) summarizes the data of many observers in terms of the brightness temperature, T_{BD}, of Jupiter's thermal disk radiation in the lower curves of Figure B-1. The band indicates, with ample uncertainty limits, the range of values reported by several observers. This curve is also used in the design criteria monograph (Ref 3) for the disk brightness temperature. As seen in Figure B-1, the nonthermal radiation contribution has been removed from the earlier curve (1967) resulting in a lower temperature that is in agreement with the latest observations. Thermal radiation from Jupiter's disk is randomly polarized and its brightness temperature is constant in time and uniform over the Jovian disk surface. The slight increase of T_{BD} with wavelength in the centimeter region implies that the radiation emerges from lower, warmer atmospheric levels at longer wavelengths. Thermal radiation is a significant contributor to the UHF radiation environment near Jupiter.

The 1971 monograph (Ref 3) also provides information for determining the noise temperature caused by the Jovian magnetosphere. Nonthermal radiation is observed from a region several Jupiter radii in extent, elongated parallel to the magnetic equator. The axis of the magnetic field is at an angle to the rotational axis and the center of the field is displaced to the south by 0.75 R_J (Ref 2, p 47). Close to Jupiter spatial distribution of the synchrotron radiation requires the use of data reported by Berge (Ref 5) and Branson (Ref 6).

The monograph (Ref 3, p 47) provides a model and equations that yield approximately correct brightness temperatures for the synchrotron source. The model is shown in Figure B-2. A volume is illustrated enclosed by a sphere of radius 3 R_J centered on the magnetic dipole and truncated by two planes parallel to and 1 R_J away from the magnetic equator. The magnetic axis is tilted from the rotational axis by 8 deg. Displacement of the magnetosphere from the planet disk center was not considered in the model. If D is the path length within the described volume in the direction of observation, the synchrotron brightness temperature, T_{BS}, is given by:

$$T_{BS} = \frac{D\lambda^2}{R_J} (0.3 \pm 0.15) \qquad [B-1]$$

with

T_{BS} = synchrotron brightness temperature, °K

D = path length, km

λ = wavelength, cm

= 30/f

f = frequency, GHz

R_J = Jupiter radius, 71,422 km.

The noise temperature of the spacecraft relay antenna is the sum of the thermal disk noise and synchrotron noise since they are considered to be two separate sources and the fluxes add directly. Initial analysis indicated that the worst-case temperature existed when both sources are within the beam of the antenna. For the nominal Jupiter probe mission (Vol. II, Section VB), this geometry exists from near entry to the end of the mission as seen in Figure B-3. The probe-to-spacecraft range decreases with range from E - 1.2 hr and then increases to entry. During descent, the range again begins to decrease as seen in Figure B-3. The maximum range during probe transmission occurs at entry and is 9.7×10^4 km or 1.36 R_J. Periapsis $(2\ R_J)$ is not reached until after mission completion. The maximum synchrotron temperature from Equation [B-1] is:

$$T_{BS} = 1.36 \times 0.45\ \lambda^2 = 0.61\ \lambda^2 \qquad [B-2]$$

and

$$T_A = T_{BD} + T_{BS} \qquad [B-3]$$

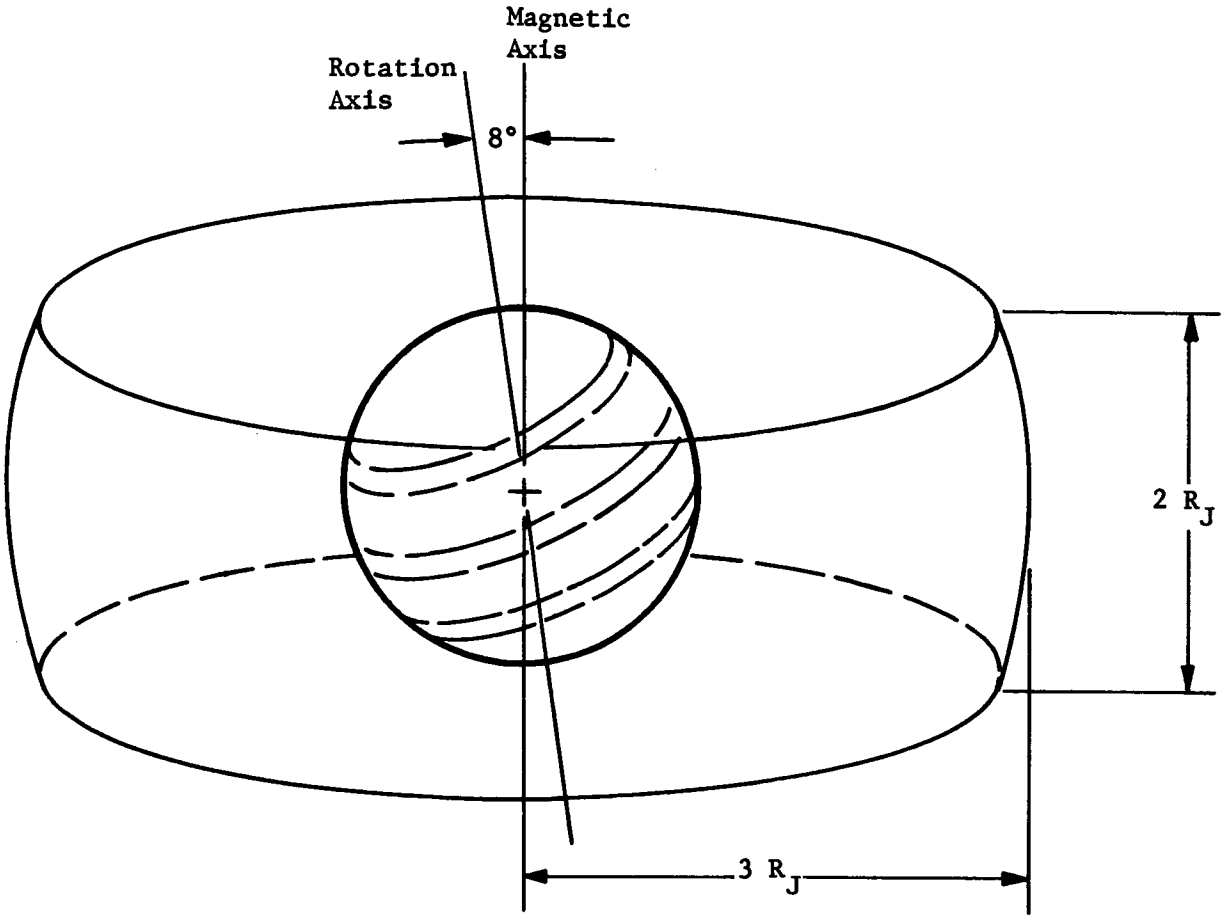


Figure B-2 Jovian Magnetosphere Model

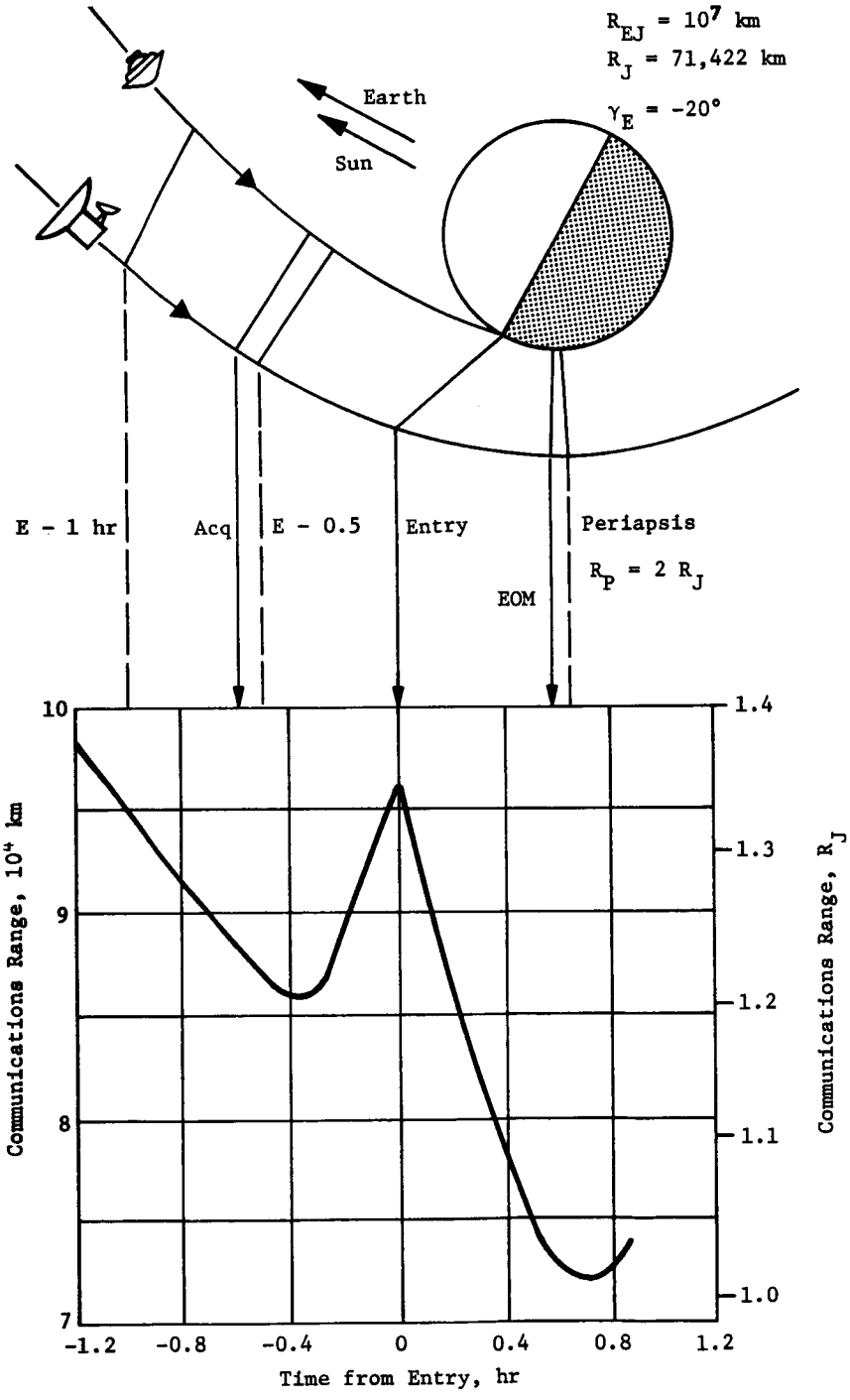


Figure B-3 Probe-to-Spacecraft Communications Range for the Nominal Jupiter Probe

The worst-case antenna noise temperature is shown in Figure B-4 and is the sum of radiation fluxes from the two sources (Equation [B-3]). The thermal disk brightness temperature is the upper limit curve of Figure B-1 from the new (1971) monograph. Results of the original study are also shown for comparison. The new curve is reduced by a factor of 6 at 1 GHz. The noise temperature contribution from the magnetosphere is a function of the spacecraft trajectory and the extent that the line-of-sight vector from the antenna to the probe intersects the magnetosphere model (Ref 7). Any periapsis radius greater than 3 R_J will penetrate the total magnetosphere model boundary and the maximum path length in the volume without intersecting the planet disk is 5.7 R_J as seen in Figure B-5. The maximum synchrotron temperature for trajectories that do not intersect the magnetosphere is given from Equation [B-1] for 5.7 R_J by :

$$T_{BS} = 5.7 \times 0.45 \lambda^2 = 2.57 \lambda^2 \qquad [B-4]$$

with the wavelength in cm and the temperature in °K. Equation [B-4] is equal to the antenna temperature if the planet disk is not within the field of view of the antenna. The thermal disk temperature must be added to Equation [B-4] if the planet disk falls within the 3-dB beamwidth of the antenna.

The curve shown in Figure B-4 was used for the spacecraft antenna noise temperature and is the worst-case condition for a mission with the spacecraft in the magnetosphere such as for the nominal Jupiter probe (Vol II, Section VB) and for the probe-dedicated Jupiter mission (Vol II, Section VC).

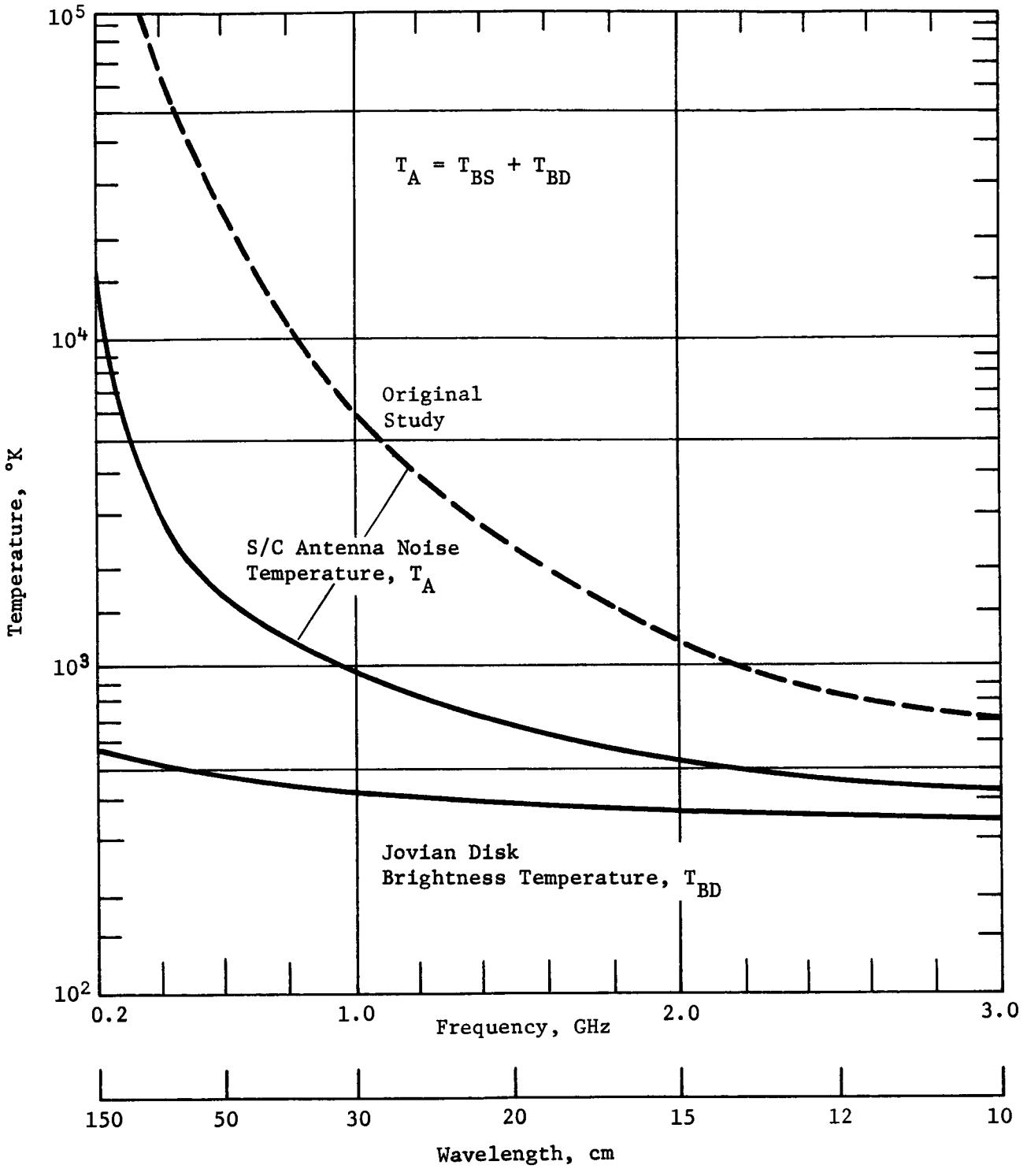


Figure B-4 Spacecraft Antenna Noise Temperature

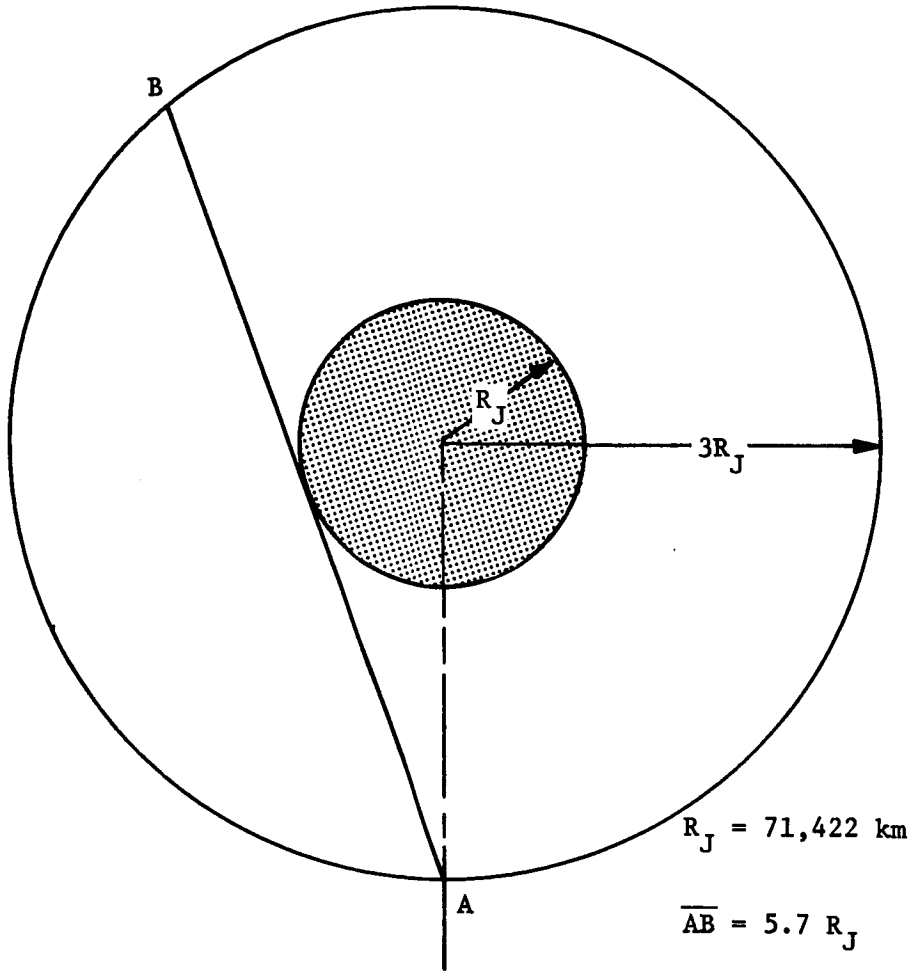


Figure B-5 Jovian Magnetosphere Penetration Distance

B. SPACECRAFT RECEIVING SYSTEM TEMPERATURE

The noise temperature of the receiving system at the receiver output is determined by the sum of the spacecraft antenna noise temperature, T_A and receiver effective noise temperature (ENT), T_R, as follows:

$$T_S = T_A + T_R. \qquad [B-5]$$

As discussed in the previous section, the antenna noise temperature, as shown in Figure B-4, is the sum of thermal disk and synchrotron noise (Equation [B-3]). The two sources of radiation, the thermal disk brightness temperature and synchrotron radiation from the Jovian magnetosphere, are added directly to determine the total spacecraft antenna temperature. Synchrotron radiation is dependent upon the relative geometry of the magnetosphere and line-of-sight vector as seen in Figure B-5.

The ENT of solid-state receivers for the frequency range of interest is shown in Figure B-6. The curves depict the temperature and noise figure (with 290°K reference) for tunnel diode and transistor receivers based upon the 1972 state of the art. An average value, one decibel above the minimum curves shown, was used in the study. As seen in the figure, the average value falls along the germanium transistor values. Using the average curve, results in the receiver ENT increasing with increasing frequency, and is 4 dB at S-band. Receiver ENT and noise figure (NF) are related by

$$NF = 10 \log_{10} \left(1 + \frac{ENT}{T_R} \right) \qquad [B-6]$$

where

NF = receiver noise figure, dB

ENT = receiver effective noise temperature, T_R, °K

T_r = ambient reference temperature, 290°K.

The spacecraft antenna noise temperature of Figure B-4 is added to the average ENT from Figure B-6 to obtain the spacecraft receiving system temperature, as shown in Figure B-7. The decrease in antenna temperature with increasing frequency is compensated by the corresponding increase in receiver ENT resulting in a nearly constant system temperature of 1000°K from 1.5 GHz through S-band.

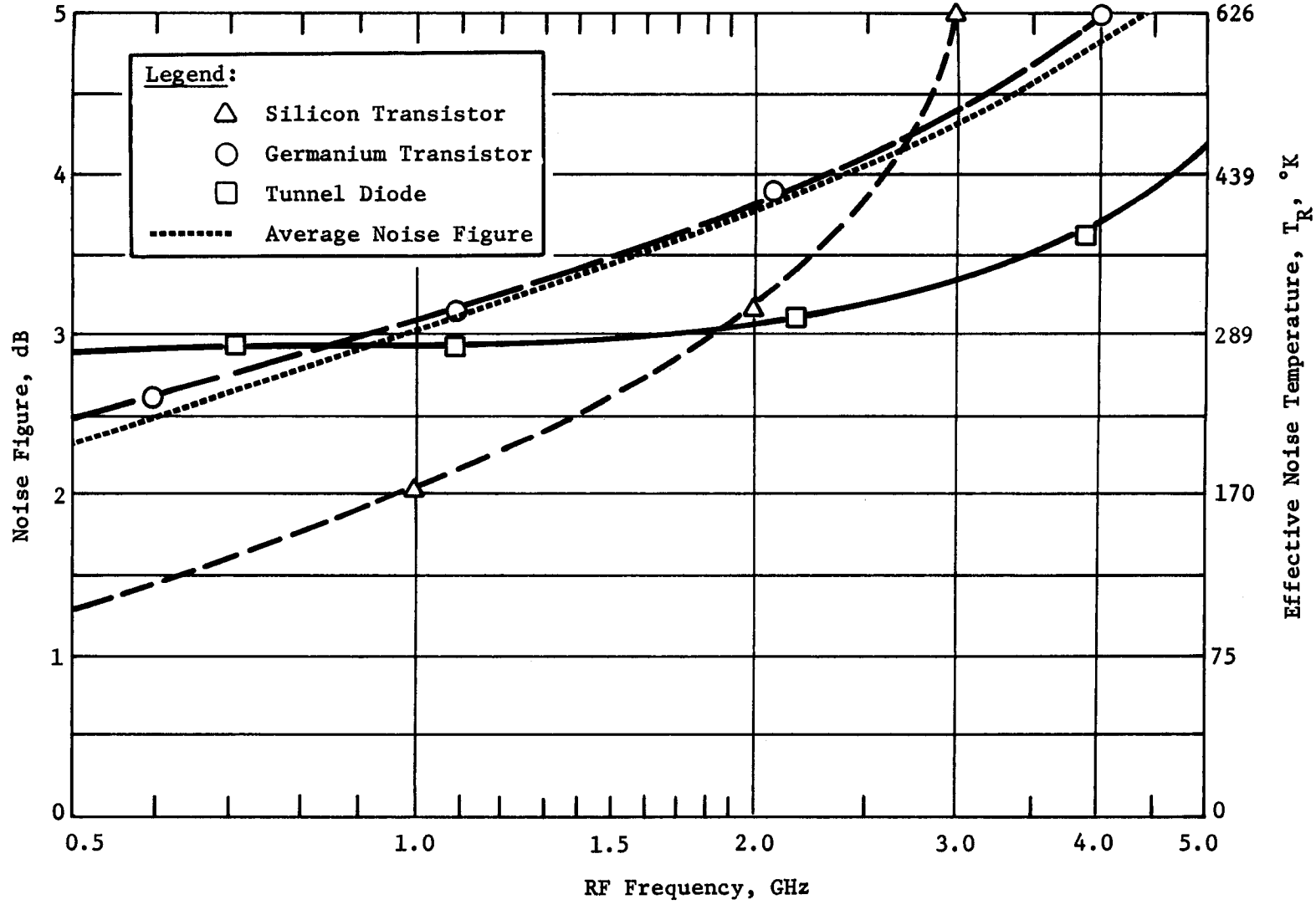


Figure B-6 1972 Noise Figure State of the Art for Tunnel Diodes and Transistor Amplifiers

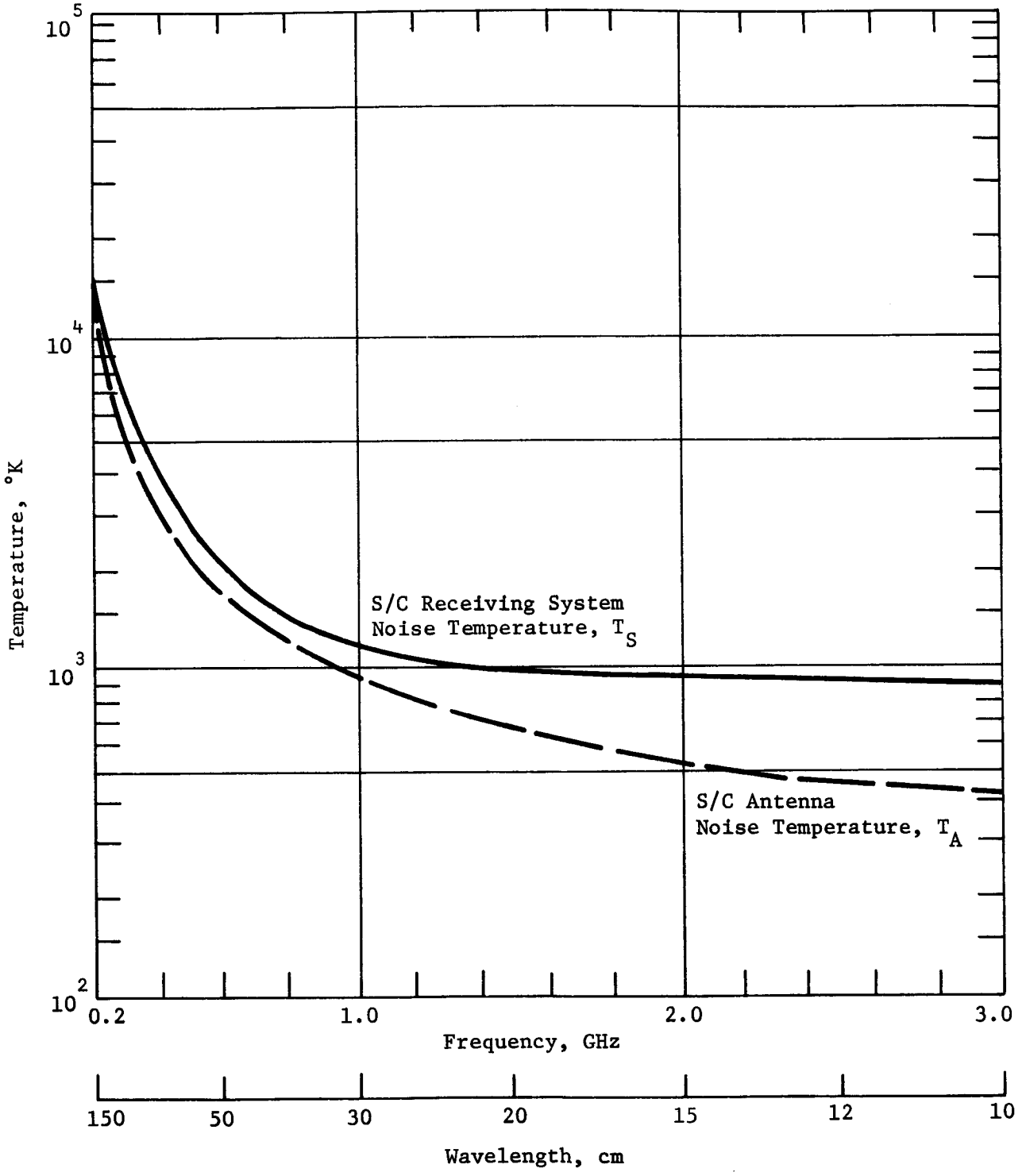


Figure B-7 Spacecraft Receiving System Temperature

C. ATMOSPHERIC ATTENUATION

The second dominant factor to be considered along with receiving system temperature is atmospheric losses. As described in detail in Appendix A, these include atmospheric attenuation due to the atmospheric constituents including clouds, as well as defocusing losses resulting from ray bending and diffraction. Figure B-8 shows the Jovian atmosphere attenuation versus frequency for the cool/dense atmosphere. The curves are for different depths into the cool/dense atmosphere at mission completion. The nominal Jupiter probe trajectory is adjusted in lead time to give decreasing probe aspect angle (ψ) versus descent time. Atmosphere absorption increases from the zenith value according to the relation

$$A_T = \frac{A_z}{\cos \psi} = A_z \sec \psi \qquad [B-7]$$

where

A_z = zenith attenuation, dB

A_T = atmosphere attenuation at path angle ψ, dB

ψ = probe aspect angle, deg.

The aspect angle for the depths shown is approximately 5 deg. The results are less than 1% greater than the zenith value (sec 5°).

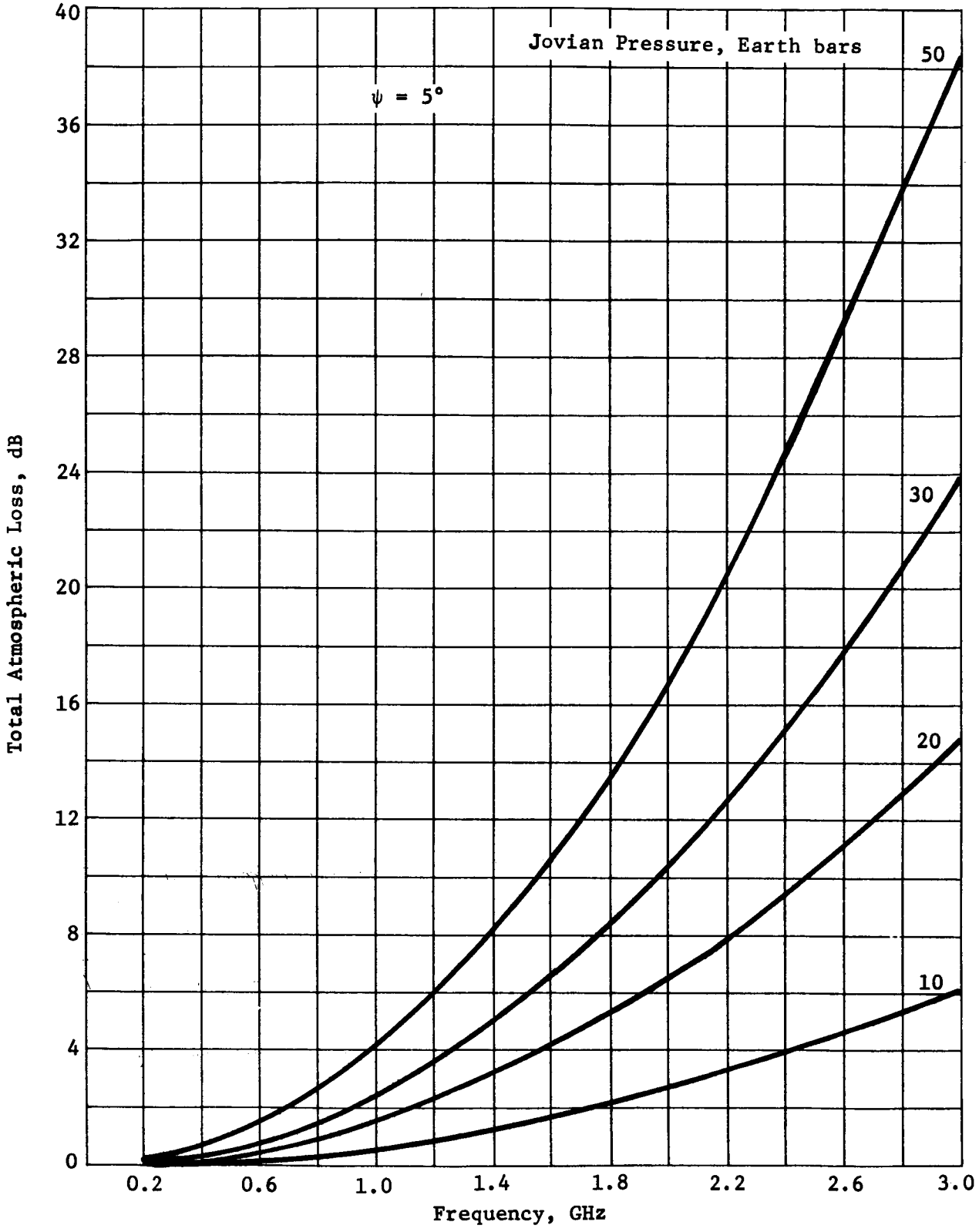


Figure B-8 End-of-Mission Attenuation for Jupiter Cool/Dense Atmosphere

D. FREQUENCY-DEPENDENT POWER REQUIREMENTS

Figure B-9 shows the relative effects on a communication link of the spacecraft receiving system temperature and atmospheric losses at a probe aspect angle of 5 deg for various descent depths as a function of frequency. The curves were obtained from the algebraic sum of Figures B-7 and B-8, with Figure B-7 converted to decibels with a reference frequency of 1 GHz. The relative power gain represents the additional link power gain required to overcome the combined effects of system temperature and atmospheric attenuation for other frequencies and penetration into the atmosphere. It is further assumed that the probe antenna gain is constant for all frequencies (constant beamwidth, variable size) and the spacecraft antenna diameter is constant (variable gain and beamwidth with frequency) such that the product of space loss and space antenna gain at any frequency of interest is constant.

The RF link computer program used in the study maintains constant probe and spacecraft antenna beamwidth and maximum gain (variable aperture size) as a function of frequency, so decreasing range will affect the relative power required. The relative power required for the nominal Jupiter probe is shown in Figure B-10 for the conditions noted on the figure. Space loss reduction and higher probe antenna gain resulting from decreasing aspect angle during descent, as seen in Figure B-11, considerably alters the shape of the curves from these shown in Figure B-9. As seen in Figure B-10, increasing frequencies above 400 MHz results in increasing relative power required to achieve a particular depth. Stated in another way, the lower frequencies are affected less by the variables in the RF link such as atmosphere loss, noise temperature, space loss, and probe antenna gain. The curves of Figure B-10 are for a trajectory optimized to 30 bars. Below 900 MHz, more power is required at entry than at a depth of 30 bars which result from trajectory optimization of range and probe aspect angle. Above 900 MHz, atmospheric loss, which is proportional to frequency, dominates and the worst-case power requirement occurs at the end of the mission (30 bars). Other various combinations can be determined from the curves in Figure B-10, keeping in mind that the probe antenna is size-limited for effective apertures equal to 22.85 cm (9 in.).

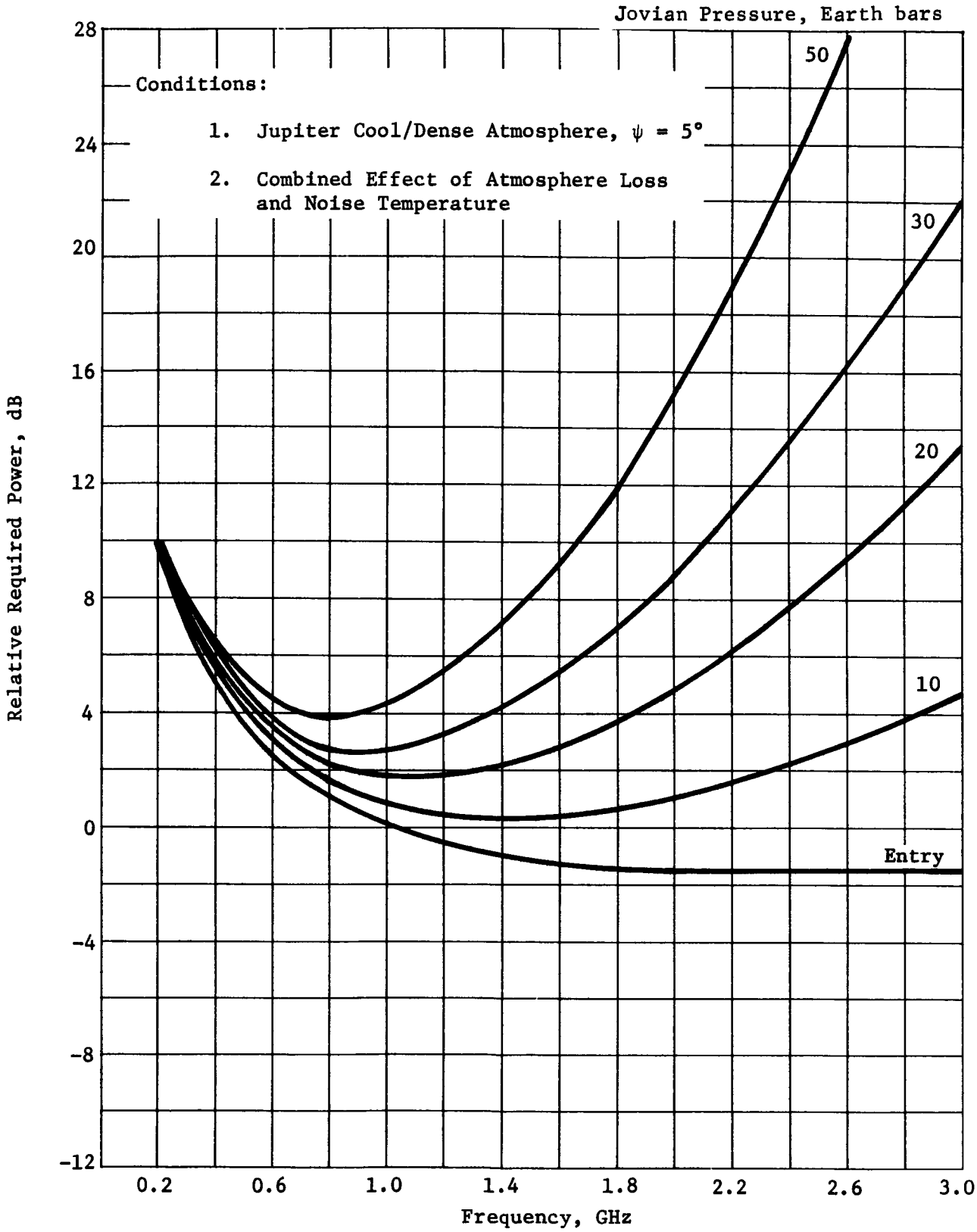


Figure B-9 Relative Required Power for the Nominal Jupiter Probe Descent with Constant S/C Antenna Diameter and Fixed Probe Antenna Gain

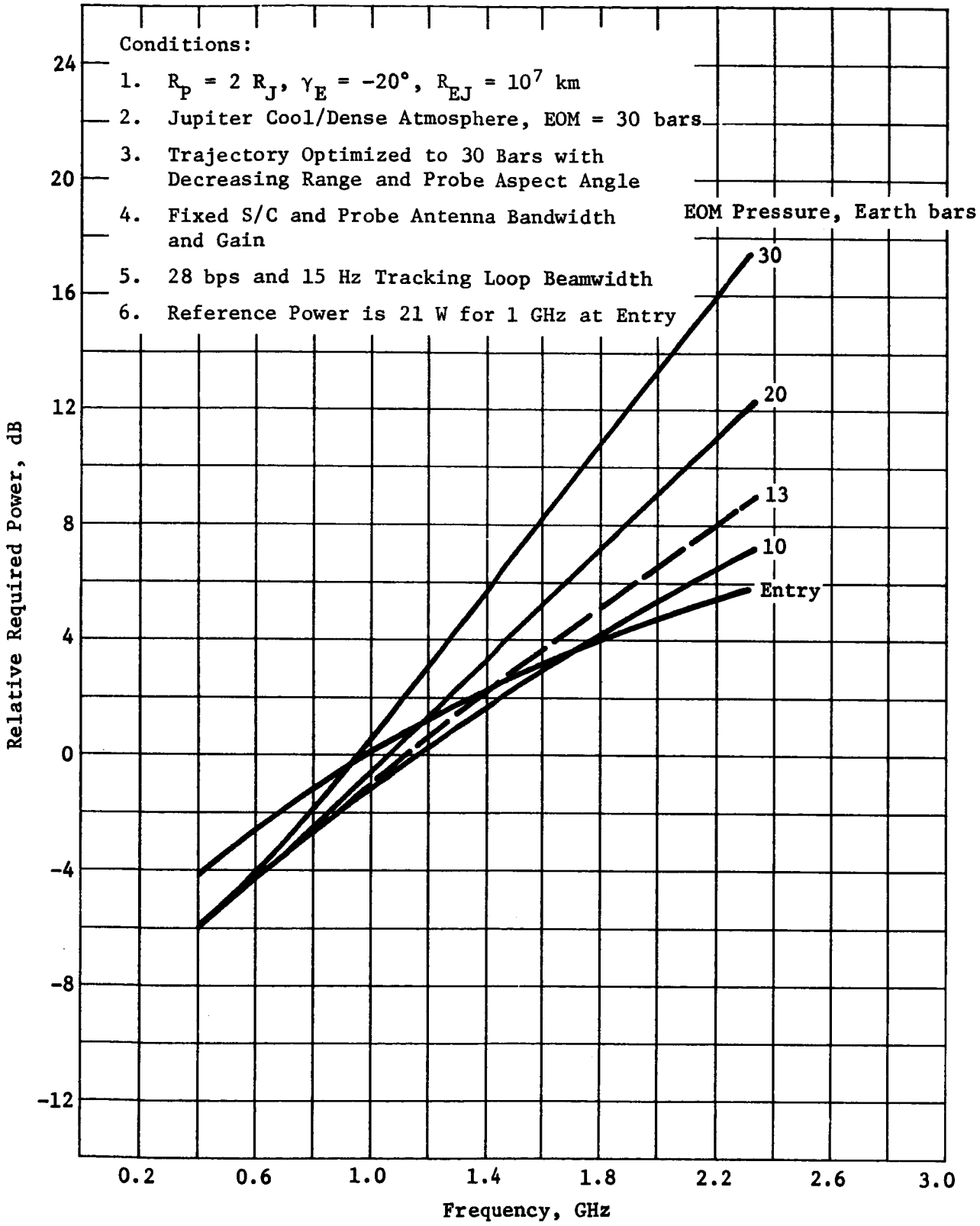
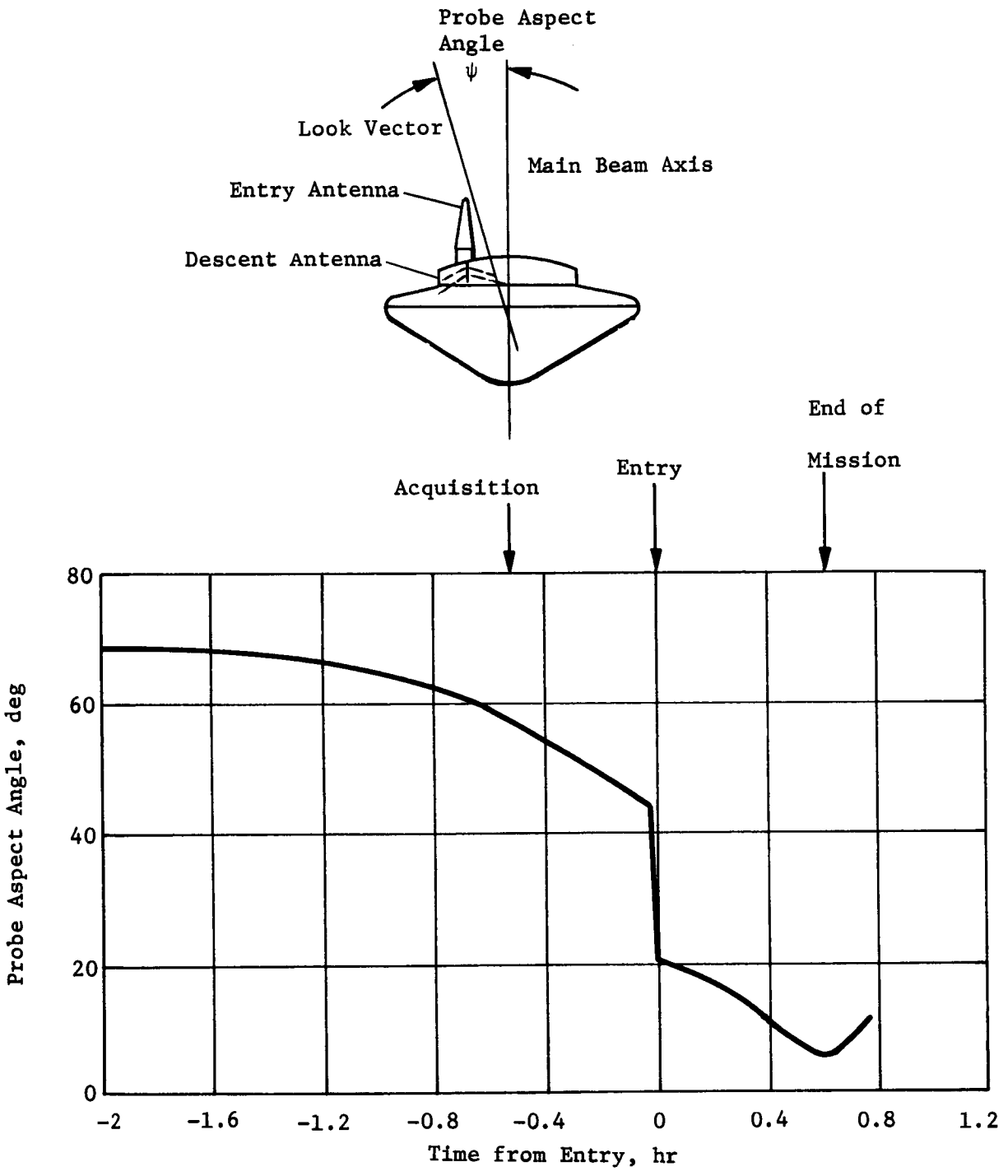


Figure B-10 Relative Power Required for Jovian Descent, Nominal Jupiter Probe



Conditions: $R_P = 2\ R_J$ $T_L = 46$ min

$R_{RJ} = 10^7$ km EOM = 30 bars

$\gamma_E = -20°$ Cool/Dense Atmosphere

Figure B-11 Nominal Jupiter Probe Aspect Angle

For simple dipole structures, we set

$$\frac{\lambda}{2} = 22.85$$

and

$$\lambda = 45.7 \text{ cm};$$

therefore

$$f = \frac{30}{\lambda} = 650 \text{ MHz}. \qquad [B-8]$$

Therefore, the minimum operating frequency is 650 MHz because of probe antenna size limits, unless a complex phased array is considered. This is not practical because of the additional costs associated with array development.

E. REFERENCES

1. *Jupiter Atmospheric Entry Mission Study Final Report*, Vol III. Contract JPL 952811, Martin Marietta Corporation, Denver, Colorado, MCR-71-1 (III), April 1971, pp IV-106 through 112

2. C. M. Michaux, *et al*: *Handbook of the Physical Properties of the Planet Jupiter*. NASA SP-3031, 1967, pp 47-56, 60-62

3. *The Planet Jupiter (1970)*. NASA Space Vehicle Design Criteria (Environment), NASA SP-8069, December 1971, pp 13-15

4. K. I. Kellermann: "Thermal Radio Emission from the Major Planets." *Radio Science*, Vol 5, No. 2, 1970, p 487

5. G. L. Berge: "An Interferometric Study of Jupiter's Decimeter Radio Emission." *Astrophysics Journal*, Vol 146, No. 3, 1966, p 767

6. N. J. Branson: "High Resolution Radio Observations of the Planet Jupiter." *Royal Astronomical Society Monthly Notices*, Vol 139, 1968, p 155

7. J. W. Davenport and D. A. DeWolf: *Investigation of Line-of-Sight Propagation in Dense Atmosphere, Phase II*. RCA Labs, Princeton, N. J. NASA CR-114288, July 1971, pp 24-34.

APPENDIX C

SPACECRAFT RECEIVER

E. A. Berkery

June 7, 1972

SPACECRAFT RECEIVER

The design of the spacecraft receiver is a function of the modulation technique, coding, Doppler uncertainty and Doppler rate. The modulation technique was selected for the purpose of evaluation rather than optimization. PSK modulation has been well studied for many applications and evaluated in the Jupiter atmospheric study.* Although PSK would provide the lowest power link, it is subject to phase disturbances in the planetary atmospheres which are largely unknown. Binary FSK modulation was therefore chosen as a less susceptible approach. This type of modulation has problem areas associated with acquisition and tracking. The possibility of receiving and recording a broadband corresponding to the frequency uncertainty was considered and discarded because of the large storage requirements on the spacecraft and the ultimate difficulty of demodulating and decoding the signal at the ground terminal. As a result, the principle efforts in the development of the spacecraft receiver configuration were directed at specifying and defining the method of tracking and acquisition. The final approach by which the data is relayed to the ground terminal may select one of several alternatives, recording a narrow pre-demodulation bandwidth or demodulation with or without decoding. A full evaluation of these alternatives involves basic communication research, is also influenced by spacecraft capability, and is considered beyond the scope of this contract.

A. ACQUISITION

The problem of acquisition was initially studied with the intent to acquire and track the data tones. First approaches considered methods for combining the two data signals, both before and after demodulation. The former was considered in systems that used a beat oscillator frequency midway between the two data tones, and two beat oscillator frequencies located at equal frequency distances from the two tones. These predetection combination methods would make maximum use of the received signal but had been discarded because of difficulty in establishing that phase coherency of the summed output signals could be achieved. Tracking and

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**Jupiter Atmospheric Entry Mission Study Final Report,* Vol III. Contract JPL 952811, Martin Marietta Aerospace, Denver, Colorado, MCR-71-1 (III), April 1971. pp IV-27 through IV-34.

acquisition of combined post detection signals had to be discarded because of insufficient signal-to-noise ratio. This approach is further compromised by the use of coding, which decreases signal power and increases bandwidth. There is an obvious tradeoff for this approach as the data rate decreases, uncoded data would provide sufficient power density in a narrow band to allow acquisition and tracking of the data signal. Also, since many of the probe missions require RF power outputs that are well below the present state-of-the-art capability, increasing the power could decrease the complexity of the spacecraft receiver as compared with the approach selected in this study. It is reasonable to consider that a flight design will provide excess margin whereever possible rather than the minimum power required by the analysis of the mission. In view of the above considerations, a link that provided a constant tone signal in addition to the binary FSK tones was finally selected as a realizable system.

The basis of the evaluation is given here and is derived directly from NASA CR-73005, Appendix G. This paper considers the acquisition of a signal, with frequency changing linearly with time, and having 99% probability of acquisition and 1% probability of false alarm. Although the reference considers a data signal, the analysis is based on a tone and is therefore appropriate to the analysis of a binary FSK system with a tracking and acquisition tone. The results of the analysis are summarized in the following equations.

$$\left(\frac{S}{N_o}\right)_a \geq 4.66\sqrt{R} + 10.86\,\frac{R}{B}$$

$$\left(\frac{S}{N}\right)_a \geq 1$$

$$\left(\frac{S}{N}\right)_T \geq 10$$

R = frequency rate of change, Hertz/sec

B = filter bandwidth

N_o = noise power spectral density

N = noise in bandwidth = BN_o

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*S. Georgiev: *A Feasibility Study of an Experiment for Determining the Properties of the Mars Atmosphere.* Final Report, Vol III, *Subsystem and Technical Analysis.* Contract NAS2-2970, Avco Corporation, Lowell, Mass. NASA CR-73005, Appendix G, September 1966.

Subscripts

a = acquisition

T = tracking

The first equation has been somewhat modified from the original (Eq [G-72] in Appendix G) for application to the probe acquisition problem. These equations are plotted in Figure C-1. A 20-dB signal-to-noise ratio line, which is pertinent to the receiver configuration and the data power for a nominal Jupiter probe design (Vol II Section V.B) is also plotted for completeness. The original goal in this design was to achieve acquisition in 100 seconds with the probabilities previously stated, and minimum acquisition and tracking tone power. The acquisition technique used here is to sweep the local oscillator with a sawtooth waveform so that the combination of sweep rate and maximum Doppler rate provides a rate of change equal to selected rate R. Initial acquisition takes place in a wide band filter/detector [$(S/N)_a \geq$ 0 dB]. The sweep rate is then decreased and final acquisition takes place in a narrow band filter [$(S/N)_a \geq 13$ dB]. The frequency tracking loop [$(S/N) \geq 10$ dB] is then activated and tracking ensues. Since the center frequency of the narrow band filter will be the same as that of the tracking filter, acquisition and lock by the tracking loop is assured. As an example,

$\Delta f = 40$ kHz (frequency uncertainty)

$T_a = 100$ sec (acquisition time)

Then $R = \Delta f / T_a = 400$ Hz/sec

Ba = 120 Hz, $P/N_o = 130$ (R = 400 Hz/sec, S/N = 0 dB).

Subsequent to initial acquisition, the sweep rate is reduced to a lower value (i.e., 100 Hz/sec) and acquisition may take place in the narrow band filter (S/N = 13 dB) in $t \leq 1.2$ seconds. The configuration of the resulting receiver is illustrated in Figure C-2. It should be noted that the P/N_o value plotted in Figure C-1 will be that appearing on the RF bus at the input to all the BPFs in Figure C-2. Since the P_D/N_o value is that required by the data receiver and is determined by the E_b/N_o figure of merit

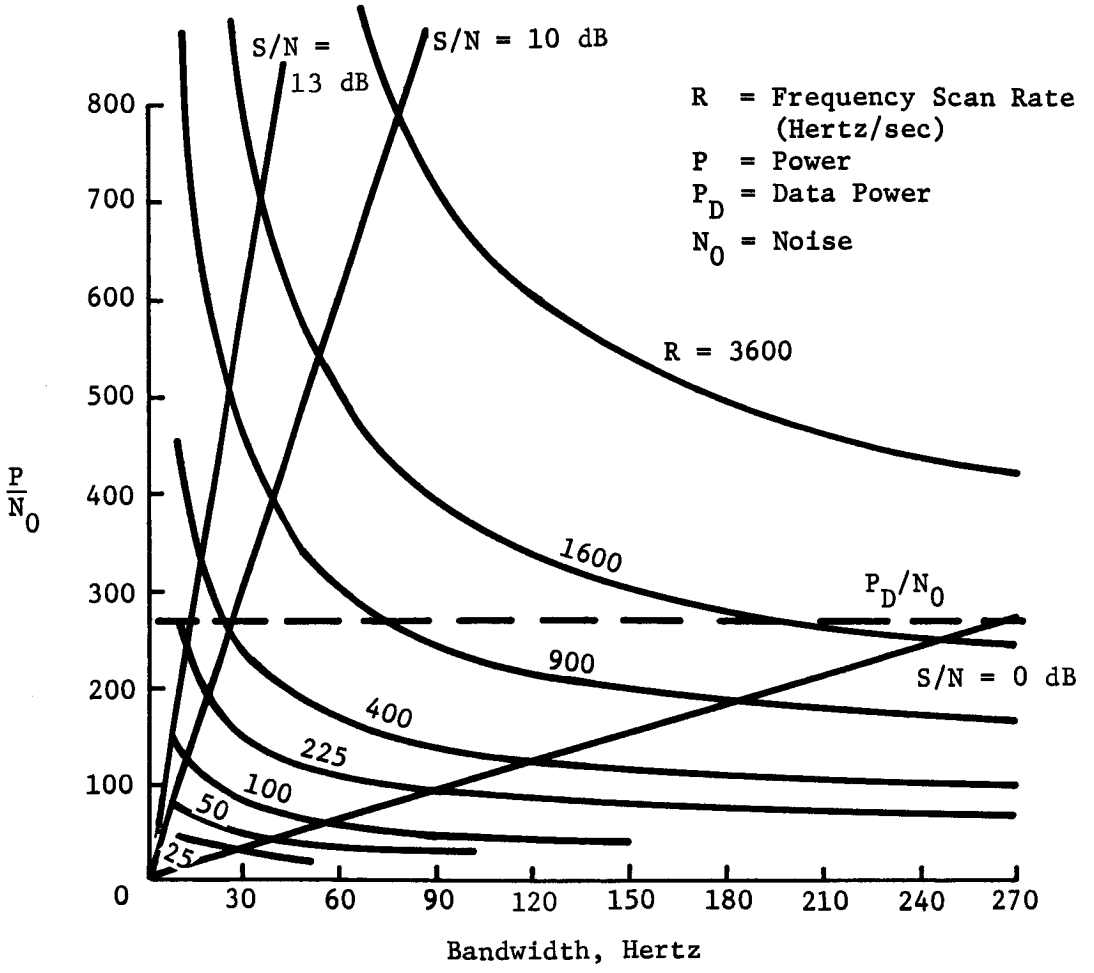


Figure C-1 Acquisition Bandwidth and Power

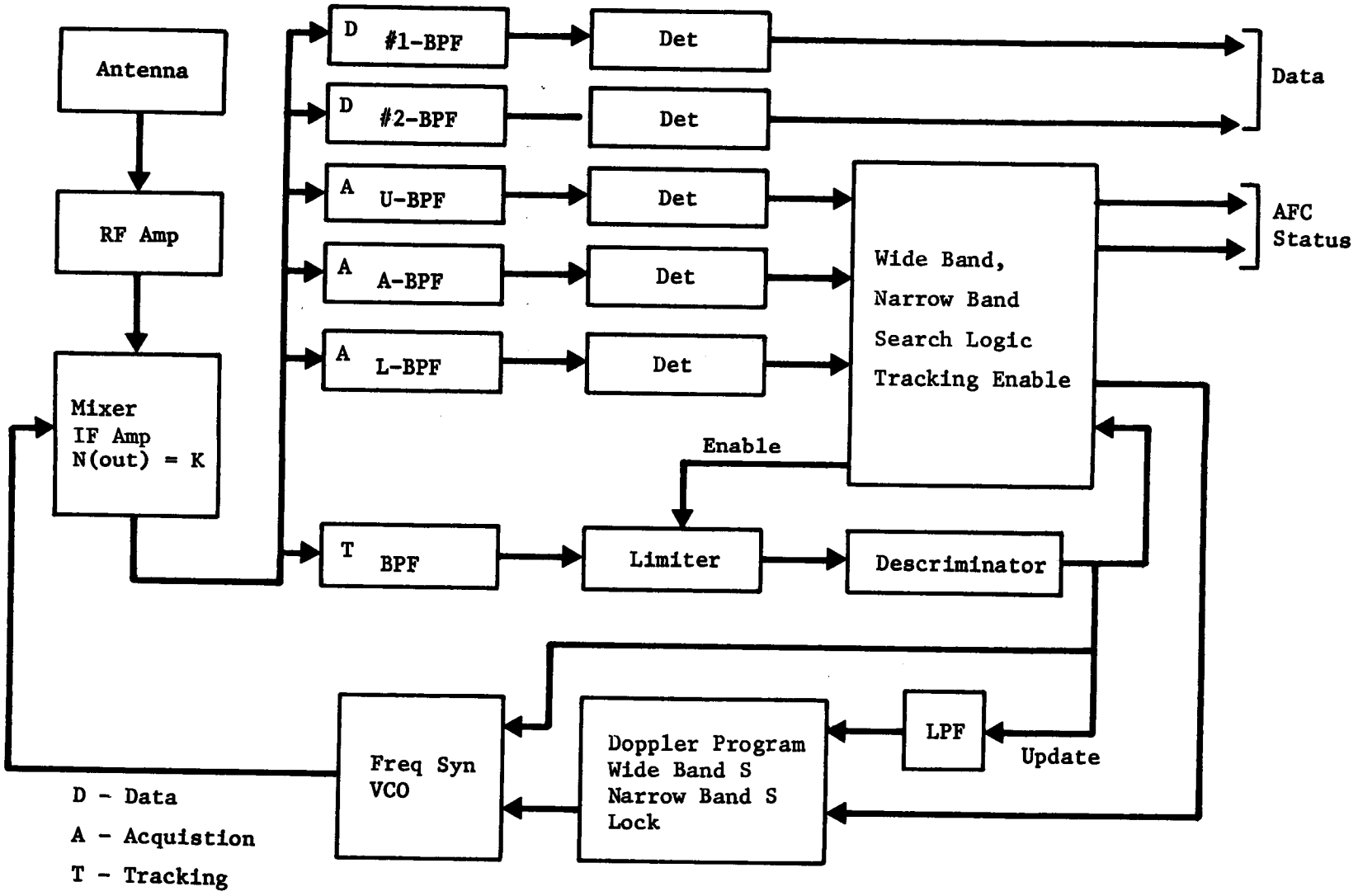


Figure C-2 Acquisition/Tracking/Data/Spacecraft Receiver

and fixed adverse tolerances, P_D/N_o is a function of the data rate which remains relatively constant for the Jupiter, Saturn, and Uranus missions. Consequently, for equal uncertainty bandwidth sweep rates, acquisition and tracking tone power is equal to approximately 50% of the data power (i.e., 1.75 dB increase in transmitter power). The tracking loop frequency uncertainty has some influence on the power in the tracking tone, since this establishes the predetection bandwidth in the tracking loop. The worst case considered was a Jupiter mission with a data link RF frequency of 2.3 GHz. The effect of the Doppler rate was to produce a maximum frequency deviation of -7.5 Hz as is demonstrated here. Although this loop stress will be relieved somewhat by a preprogrammed frequency shift in the tracking loop, a 15 Hz bandwidth was selected for the tracking loop BPF for all mission. This has the effect of fixing the received tone power at P/N_o = 150 and R(Max) = 400 for all missions. The effect of differing uncertainty bandwidth/frequency is to change the acquisition time. Some transmission power reduction can, in general, be achieved by decreasing the tracking BPF bandwidth and increasing acquisition time; however, approximately 1.0 dB is the maximum improvement that should be expected.

The characteristics of the BPFs of Figure C-2 in the frequency domain are shown in Figure C-3. The figure is not to scale for purposes of illustration. The IF frequency bandwidth is approximately equal to the total possible variation from nominal of the received probe frequency. The data BPFs bandwidth are of the order of the bit rate plus frequency tracking deviation. The high rate acquisition filters (A/U, A/L) may overlap slightly to provide logic signals during tracking. The narrow band acquisition filter (A/A) is located at the junction of the two wideband filters. The tracking filter is located symmetrically with respect to the narrow-band acquisition filter. The local oscillator frequency will be swept from low to high frequency so that the difference (IF) frequency will sweep from high to low frequency. Under these circumstances, the upper acquisition BPF will detect the probe signal first and will not be perturbed by data signals. When the search logic registers a wide-band, (A_U) acquisition, it will decrease the sweep rate to enable acquisition in the narrow band (A_A). Once acuqisition is achieved in narrow band, the sweep is discontinued and the tracking loop is enabled.

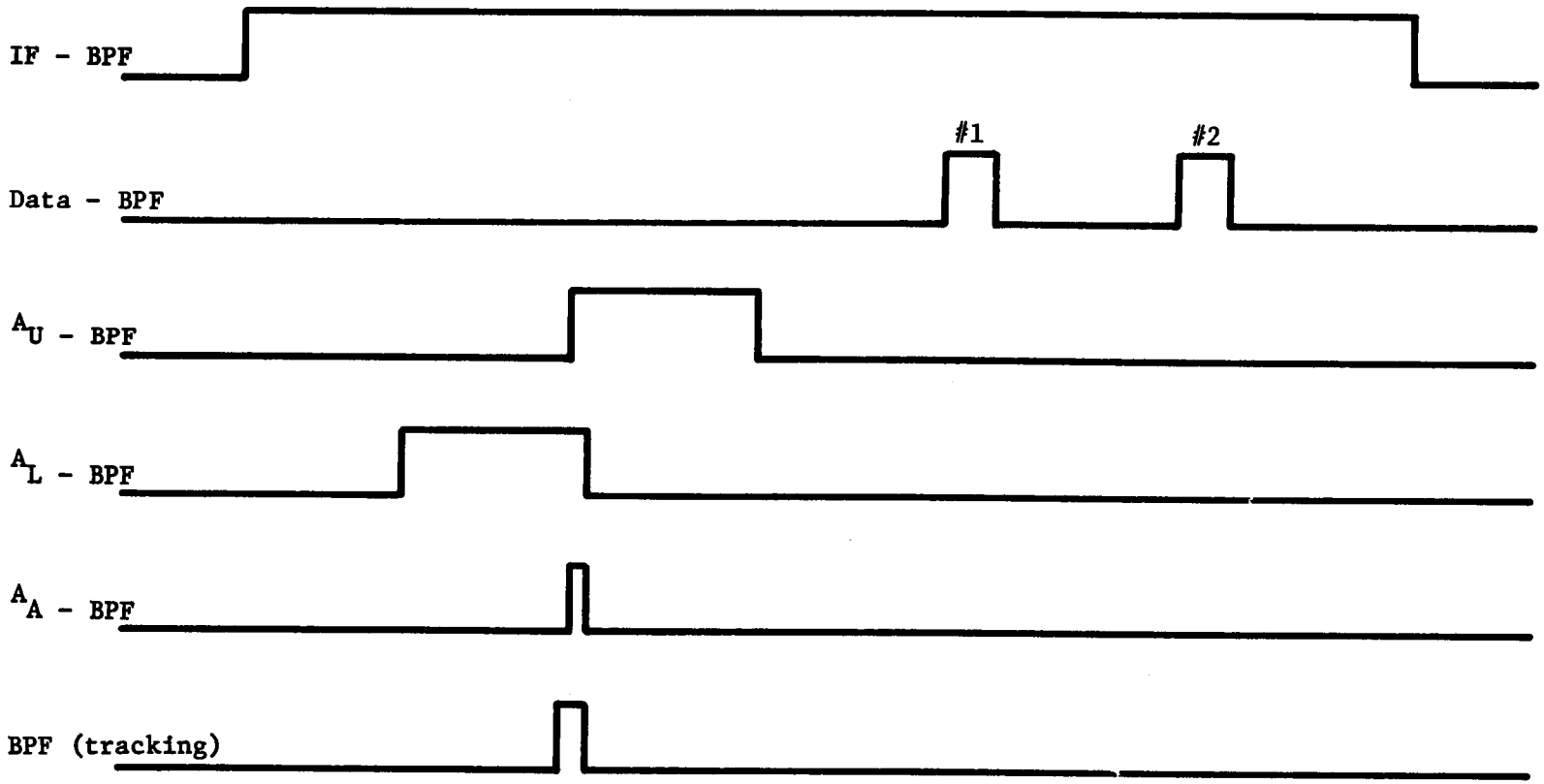


Figure C-3 Receiver Bandpass Characteristics

In the event that the narrow band does not acquire, the lower wide band (A_L) will register acquisition within a fraction of a second (i.e., broad-band acquisition response time is approximately 0.3 sec) after the signal moves into the lower bandpass. The search logic will respond to acquisition of the signal in A_L and loss of acquisition in A_U by reversing the slow sweep rate and driving the signal higher in frequency and back into the narrow bandpass, A_A. This logic is illustrated in Table C-1. The first six lines have been discussed. The last two lines could conceivably occur because of variations in signal strength and degrees of overlap of the BPFs. Loss of signal could occur due to a noise burst or a system transient. It may be desirable to include some time delay between logic transitions for this type of disturbance. The analysis of the detection probabilities uses integrate and dump configurations. The acquisition circuitry should therefore continuously sample (time = t), store, sum, and dump samples acquired at previous times which are in excess of the design hold period (τ). The output of the circuitry would then be

$$E_o = \int_{t-\tau}^{t} edt$$

Since the analysis is also based on threshold levels, the gain of the wide band IF amplifier may be controlled by its own noise output which should predominate. No problem is anticipated if the probe signal is strong enough to affect the gain control. The condition to be achieved is to maintain the noise level in the absence of signal below the desired threshold. In the presence of a strong signal, it is advantageous to depress the gain further and avoid excessive clipping with resultant signal-to-noise ratio loss.

Table C-1 Search and Acquisition Logic

A_L	A_A	A_U	Logic State
0	0	0	Sweep Down/High Rate
1	0	0	Sweep Up/Low Rate
1	1	0	Frequency Hold/Enable Track
1	1	1	Frequency Hold/Enable Track
0	1	1	Frequency Hold/Enable Track
0	0	1	Sweep Down/Low Rate
0	1	0	Maintain Previous State
1	0	1	Maintain Previous State

B. TRACKING

The tracking loop and its equivalent servo loop are shown in Figure C-4. The evaluation of this loop follows.

Open loop gain

$$\left.\frac{W_o(S)}{W_i(S)}\right|_{OL} = K_D\, K_V\, B_n(S)\, B_t(S) \qquad [C\text{-}1]$$

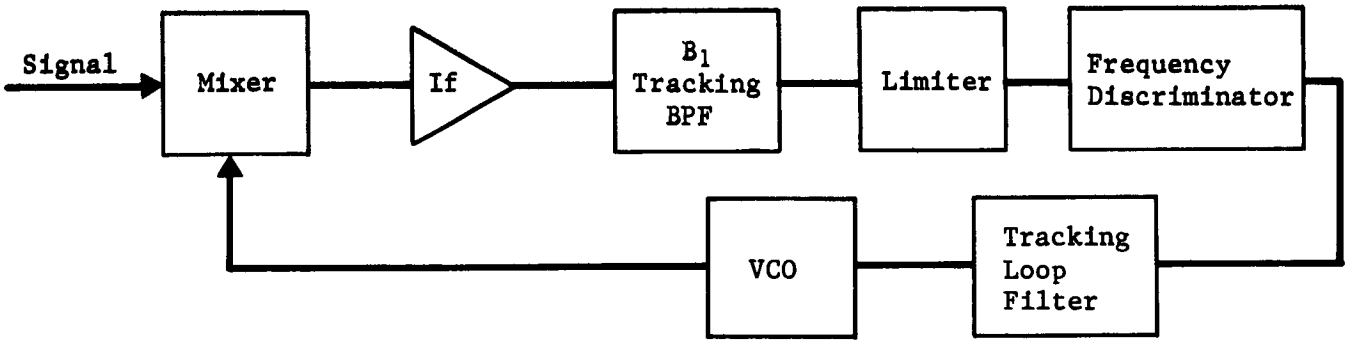
Let

$$K = K_D\, K_V \qquad [C\text{-}2]$$

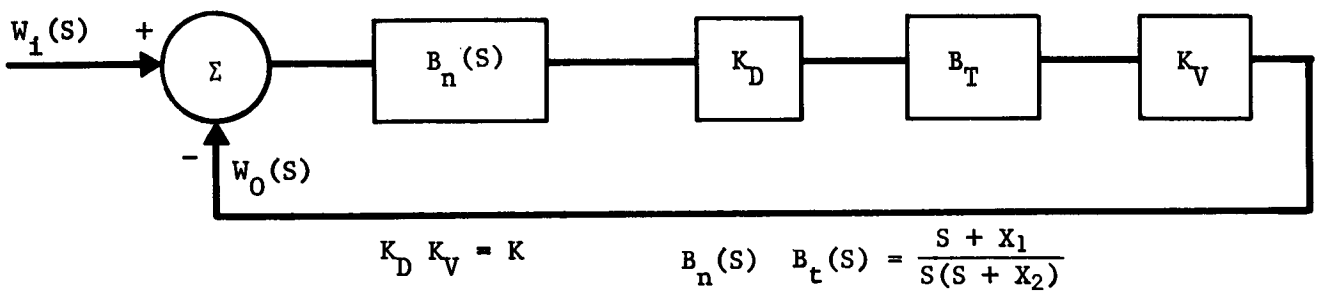
$$B_n(S)\, B_t(S) = \frac{S + X_1}{S(S + X_2)} \qquad [C\text{-}3]$$

where Equation [C-3] assumes a second order loop and implies

$$(\text{Bandwidth})_n >> (\text{Bandwidth})_t. \qquad [C\text{-}4]$$



A. a. AFL Loop Configuration



b. Equivalent Servo of AFC Loop

Figure: C-4 AFC Loop

The problem consists of selecting loop parameters such that the tracking error due to Doppler rate is acceptable. It is assumed that acquisition has already been achieved. The input is assumed to be a ramp in frequency with slope equivalent to the maximum Doppler rate.

$$W_i(S) = \frac{\dot{W}_d}{S^2} \qquad [C\text{-}5]$$

$\dot{W}_d$ = maximum Doppler rate [C-6]

The closed loop gain is

$$\frac{W_o(S)}{W_i(S)} = \frac{K(S + X_1)}{S(S + X_2) + K(S + X_1)}$$

$$\frac{W_o(S)}{W_i(S)} = \frac{\frac{1}{X_1}(S + X_1)}{\frac{S^2}{KX_1} + \left(\frac{K + X_2}{K X_1}\right) S + 1}$$

Denominator analysis

$$\frac{S^2}{X_\eta^2} + \frac{2\zeta}{X_\eta} S + 1 = \frac{S^2}{K X_1} + \left(\frac{K + X_2}{K X_1}\right) S + 1$$

$X_\eta^2 = KX_1$ = Closed loop bandwidth

$$= \frac{X_\eta}{2}\left(\frac{K + X_2}{K X_1}\right) = \text{Damping Coefficient}$$

Steady-State error

$$\Delta W_{SS} = \lim_{S \to 0} S\,[\Delta W(S)]$$

$$\Delta W(S) = W_i(S) - W_o(S)$$

and

$$\Delta W_{SS} = \lim_{S \to 0} S \left[\frac{\dot{W}_D}{S^2} \frac{S(S + X_2)}{S(S + X_2) + K(S + X_1)} \right]$$

$$\Delta W_{SS} = \frac{\dot{W}_D X_2}{K X_1}$$

The selection of K, X_1, X_2, determines the dynamic transient characteristics and steady-state error. These factors in an optimum design would determine tracking filter bandwidth and tone power. It is sufficient here to select values that define a realizable system.

Hence, set $K = 4$ $X_1 = 2.25$ H_z $X_2 = 0.25$ H_z

Closed loop bandwidth = $KX_1 = 3$ Hz

$\dot{W}_D = 70$ Hz (Alternate Jupiter Probe: 6 R_j, 0.86 GHz t = E-0: see Vol II, Section V.D)

$\Delta W_{SS} = 1.95$ H_z

Assuming a tone line bandwidth of 2 Hz, the expected frequency deviation subsequent to lock is,

$W = \pm 3.95$ Hz

The plus/minus sign tends to be conservative since the Doppler rate is always negative. From the above, if a factor of 1.9 is allowed for acquisition and noise transients, the tracking filter bandwidth becomes

$(BPF)_t = 15$ Hz

Although this mission is essentially a worst case, the same tracking bandwidth is used on all missions. It should be noted that the acquisition transient has not been evaluated. The factor of 1.9 is conservative and this initial transient can essentially be reduced by variuous acquisition logic approaches. With the design constants given above,

Damping coefficient $\zeta = 0.707$

Loop phase margin $\theta_m = 43°$

The effect of noise on the system has not been evaluated. However, the link analysis allows

$(S/N)_T = 10$ dB

The noise will cause some additional deviation of the frequency which is considered to be well within the conservatism of the above design. A more rigorous evaluation of the effects of narrow band noise in the presence of signal, acquisition transient and transmitter frequency perturbations (line width) is indicated, but it is not expected that the results would change the above feasibility evaluation. For the purpose of evaluating the effects of frequency deviation on various missions:

Nominal Jupiter Probe	1.0 GH_z	$\dot{W}_D = 65$ Hz	$\Delta W = 3.8$ Hz	(See Vol II, Section V.B)
Spacecraft Radiation Compatible Alternate Probe	0.86 GHz	$\dot{W}_D = 70$ Hz	$\Delta W = 3.95$ Hz	(See Vol II, Section V.D)
Saturn Probe	0.86 GHz	$\dot{W}_D = 26$ Hz	$\Delta W = 2.72$ Hz	(See Vol II, Section VI.B)
Uranus Probe	0.86 GHz	$\dot{W}_D = 21$ Hz	$\Delta W = 2.58$ Hz	(See Vol II, Section VII.B)

APPENDIX D

MISSION ANTENNA ANALYSIS AND DESIGNS

R. E. Compton, Jr.

June 23, 1972

MISSION ANTENNA ANALYSIS AND DESIGN

Several types of antennas are required on the spacecraft and probe with axial and butterfly patterns to satisfy trajectory requirements. The contract did not specifically require detailed hardware designs but greater detail was required in order to perform mechanical design and configuration integration. Antenna sizes and weights were necessary in order to calculate mass properties and probe weights. The payload fairing also limits the size of a probe tracking dish to 1.5 m (60 in.) in order to fit within the payload envelope.

The probe spins about its longitudinal axis to maintain attitude stability. Therefore, circular polarization will allow the probe to rotate without the received energy being affected significantly by cross-polarization. A small loss does exist from pattern ellipticity and ripple. If linear polarization were used for the probe antenna, loss of 3 dB or more would be encountered depending upon the look vectors at the transmitting and receiving antennas and the extent of the respective aspect angle off boresight of the main beam patterns.

Several types of antennas were chosen for each application and a final type was based upon size, weight, polarization, side lobe level, maximum gain, and pattern shape. The designs described herein and used on the various missions are preliminary and subject to design refinements. The primary objective was to determine envelope size and weight. Such design details as feed techniques and the possibility of RF breakdown were not investigated in depth.

A. SPACECRAFT ANTENNAS

The antennas selected for the spacecraft are of two designs depending upon the required beamwidth. For a mission, such as shown in Figure D-1, the beamwidth requirements are small and a dish antenna provides an efficient design. For large beamwidths, such as shown in Figure D-2, a dish antenna becomes too inefficient at UHF and a low gain antenna such as a helix was selected. A conventional parabolic dish antenna, fed by a pair of crossed dipoles in a cup, and a helix antenna both provide the required circular polarization. The sense of polarization is not important as long as both transmitting and receiving antennas have the same sense; i.e., right-hand or left-hand circular patterns.

The spacecraft antenna platform must be despun on spacecraft such as Pioneer which is spin stabilized. Spacecraft such as TOPS, MOPS, or Mariner that are three-axis stabilized, do not require a despun platform. Despinning is required in order to maintain a fixed pointing direction of the antenna in space. As seen in Figures D-1 and D-2, relative probe motion is greater in cone angle than in clock or elevation (cross cone) angle. Elliptical patterns were not required to increase the gain. A circular pattern provides a more conservative design from the standpoint of compensating for position errors in the probe.

Parabolic dish antenna gain is based on an efficiency of 55% with a focal length (f/d) of 0.3 and uniform aperture illumination. The sidelobe level has maximum suppression under these conditions (>20 dB) and the subtended angle of the reflector is 159°. The maximum gain is calculated from

$$G_m = 10 \log_{10} \left[0.55 \pi^2 \left(\frac{d}{\lambda} \right)^2 \right] \qquad [D-1]$$

where

G_m = maximum dish gain, dB

d = dish diameter, cm

λ = wavelength, 30/f, cm

f = operating frequency, GHz.

The half-power (-3 dB) beamwidth in degress is symmetrical in both the E and H planes and equal to

$$\theta_{hp} = 70 \frac{\lambda}{d}. \qquad [D-2]$$

Probe position dispersions, such as shown in Figure D-1, were used for each mission to determine minimum spacecraft antenna beamwidth. The launch vehicle payload fairing envelope restricts the stowed spacecraft antenna dish size to 1.5 m (60 in.) in order to clear the fairing. As seen from Equation [D-2], the dish diameter, d, is inversely proportional to the 3-dB beamwidth. A dish with this diameter at 0.86 GHz has a beamwidth of 17°. At 1 GHz the minimum beamwidth is 14°. Therefore, a size limitation was not necessary on the spacecraft dish antenna.

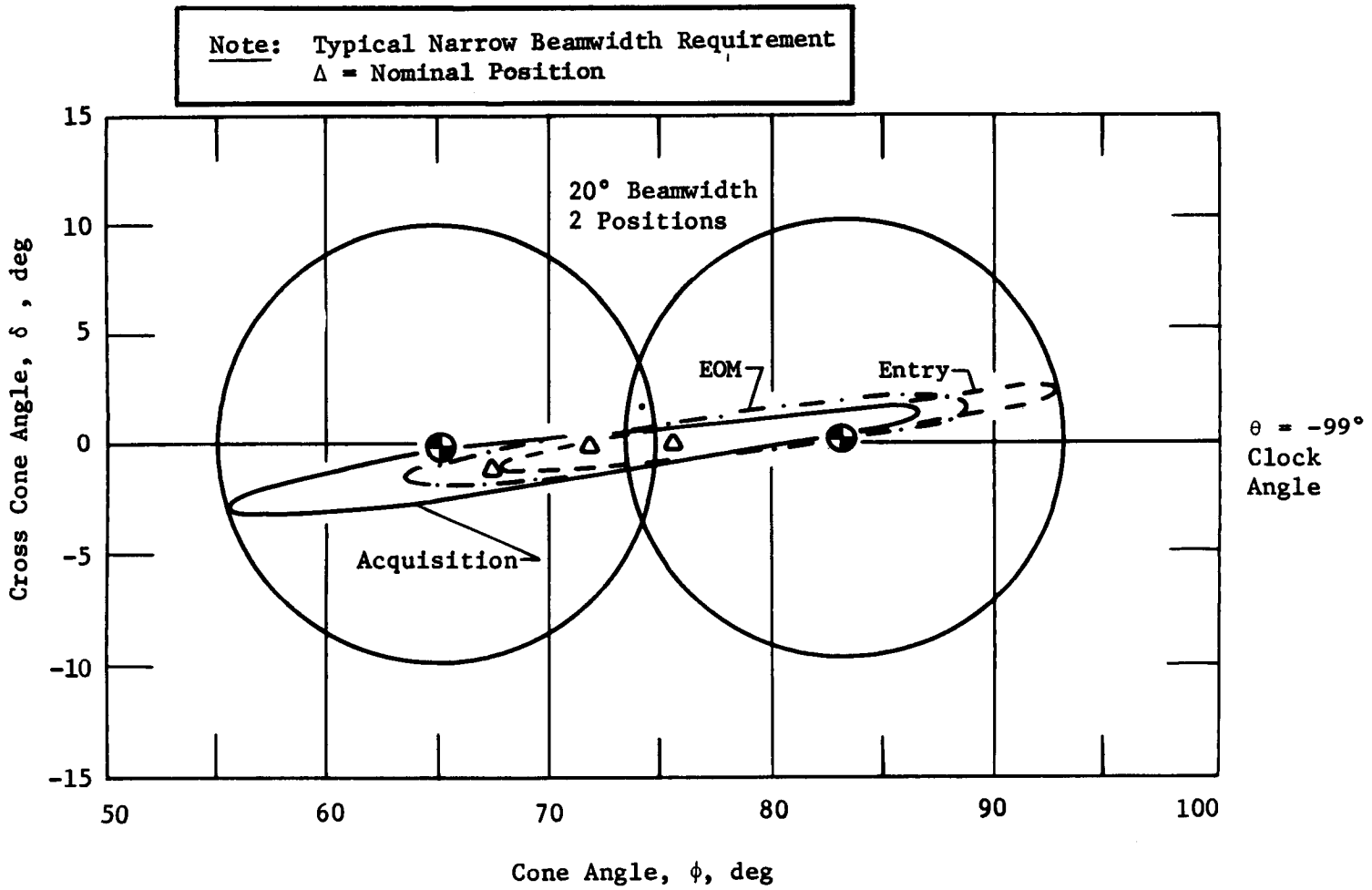


Figure D-1 Spacecraft Antenna Requirements for Jupiter Mission Point Design 8

Note: Typical Broadbeam Antenna Requirement
Δ = Nominal Position

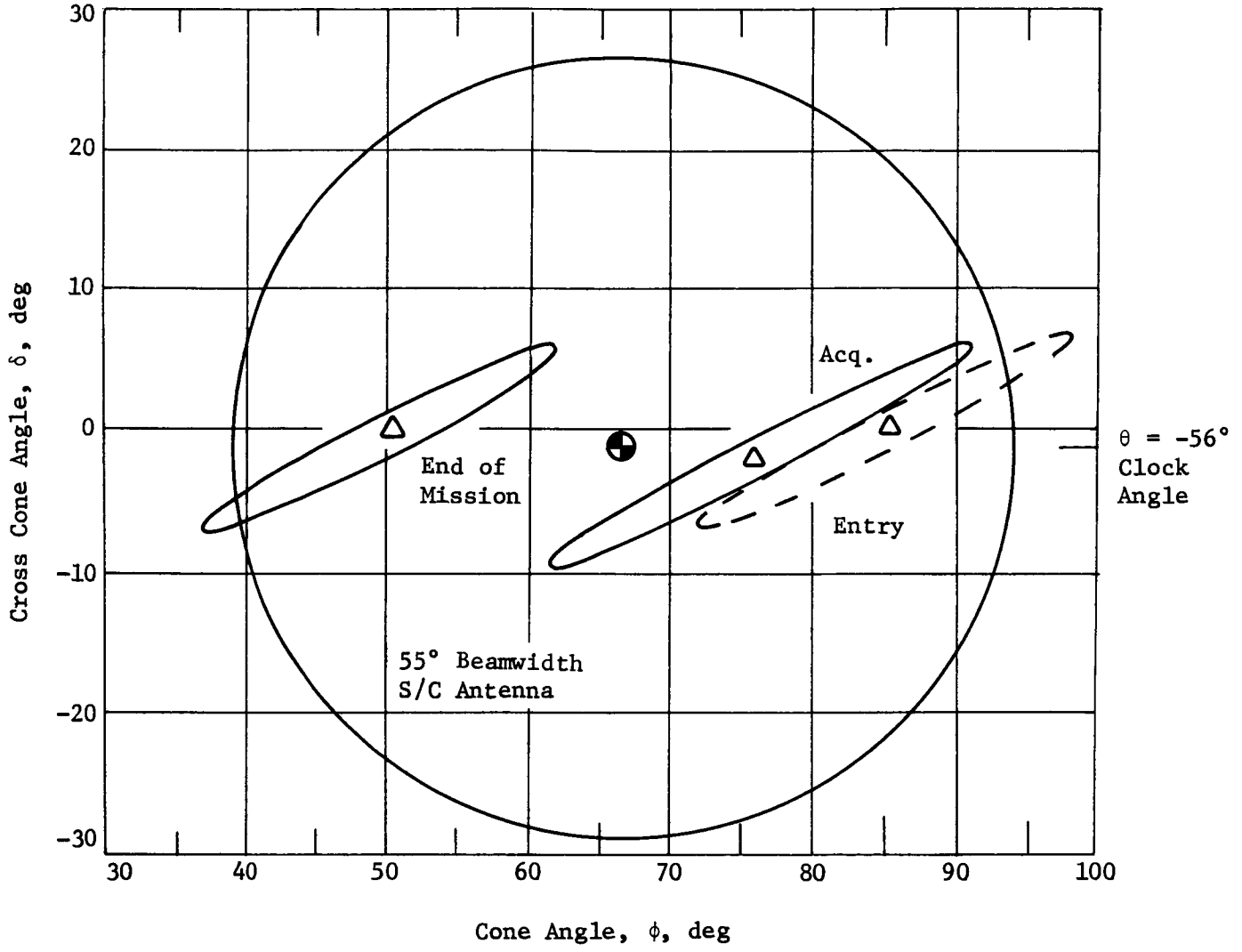


Figure D-2 Spacecraft Antenna Requirements for the Jupiter Probe Dedicated Mission

A parabolic dish provides a compact design with circular polarization up to approximately 30° at 1 GHz, and for larger beamwidths the dish diameter is less than 0.75m (2.5 ft) and the feed mechanism becomes a problem in size (aperture blockage) and efficiency. For this reason, a helix was selected for large beamwidths. Helical antennas are commonly used on spacecraft for low gain applications requiring circular polarization. For a beamwidth of 30° at 1 GHz, a 13-turn helix is required that is 3 λ (0.9 m) long. Larger beamwidths are smaller in length for a fixed frequency so the payload fairing size limitation is not a problem because of excessive length.

An optimum design for an axial mode helix has a circumference equal to the wavelength and a slant angle on the loops of 12.5°. Under these conditions, the maximum gain is equal to

$$G_m = 12\ L_\lambda\ C_\lambda^2 = 12L_\lambda \qquad [D\text{-}3]$$

where:

G_m = maximum gain ratio

C_λ = 1, circumference in wavelengths

α = 12.5°, loop slant angle

L_λ = axial length in wavelengths = n S_λ

n = number of turns

S_λ = loop spacing in wavelengths.

The half-power beamwidth, in degrees, is symmetrical in both planes and, for C_λ = 1, equal to

$$\theta_{hp} = \frac{52}{C_\lambda\sqrt{L_\lambda}} = \frac{52}{\sqrt{L_\lambda}}. \qquad [D\text{-}4]$$

These relationships are depicted in graphical form in Figure D-3. The circumference may be varied between 0.8 and 1.2 λ. For larger diameters with a given beamwidth, the length and number of turns are reduced, as seen in Figure D-3. A value of one C_λ results in an optimum ratio of diameter to length, D/L.

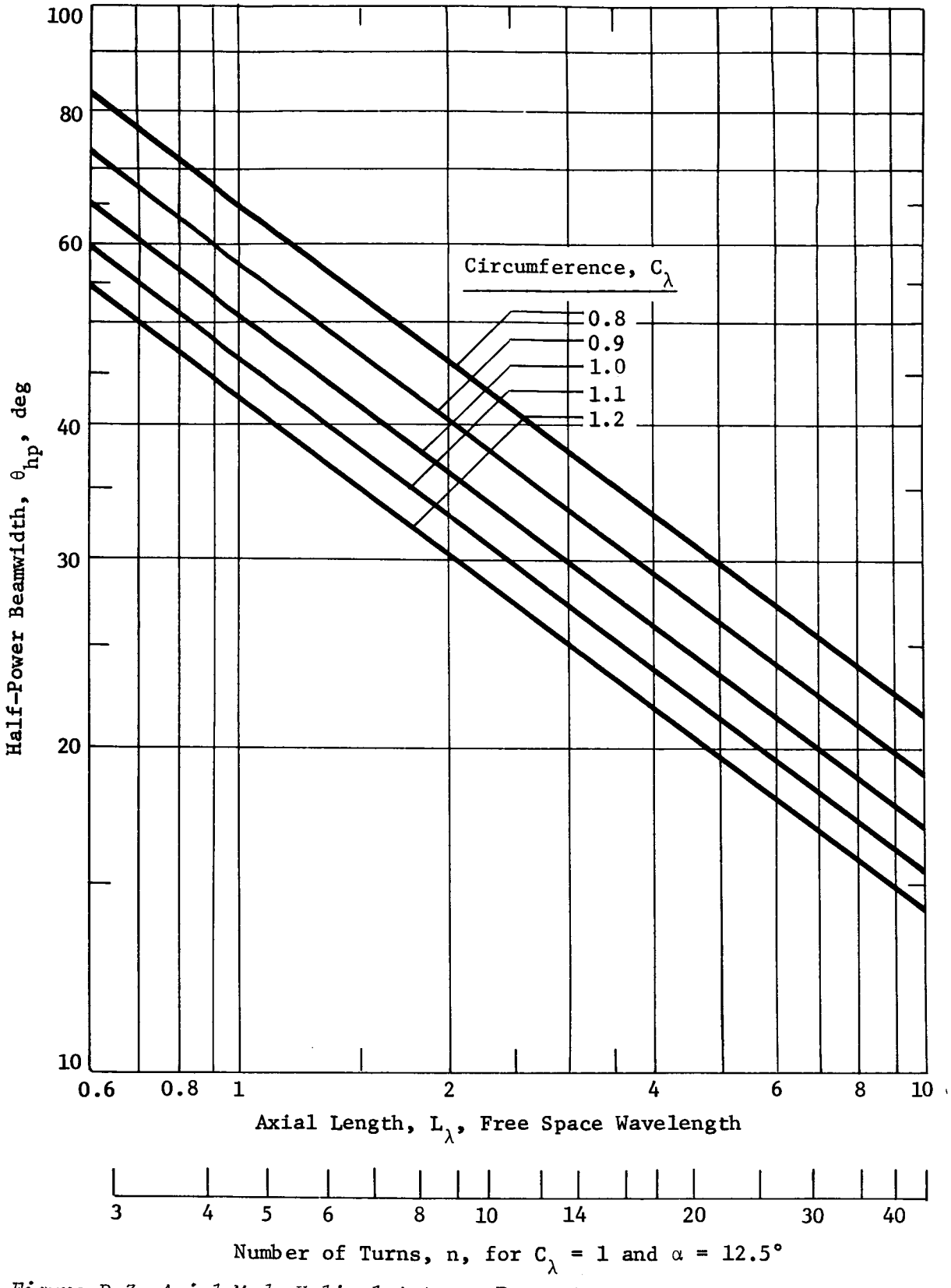


Figure D-3 Axial Mode Helical Antenna Parameters

Beamwidths on the order of 50° to 60° result in 5 turns or less, and an axial length less than λ (30 cm for 1 GHz). As seen, the helical antenna provides a compact design for low-gain applications (Ref D-1).

2. Probe Entry Antenna

Probe aspect angle during acquisition and initial descent is typically on the order of 50° to 60°. Dispersions in the angle are usually small, which result in small beamwidths requirements.

Since the probe is spin stabilized, a butterfly antenna pattern is required. For the orignial higher frequencies anticipated, a four-arm equiangular spiral on a cone was selected. The truncated cone length is 0.9 λ and base diameter is 0.75 λ. For 0.86 GHz, the cone dimensions become excessive and another design was considered. An annular slot antenna was selected to be used at this frequency. It is 43 cm (17 in.) in diameter and only 1.9 cm (0.75 in.) thick, and is placed under the deflection motor. The main drawback to this design is that the antenna is linearly polarized and cross-polarization loss is 3 dB with a circularly polarized spacecraft antenna. Annular slot antennas are very popular for airborne use in communications, and provide a butterfly pattern that is adjustable to a small degree by variations in design parameters. Printed circuit feed techniques are common. The annular slot entry antenna for 0.86 GHz is shown in Figure D-4 (Ref D-2).

3. Probe Descent Antenna

The descent antenna on the probe is also of two designs depending on the mission and frequency. For 1 GHz, a crossed dipole in a cup was chosen. For circular polarization, the dipoles are unequal in length. The longest dipole is 18.75 cm (7.4 in.) long. The antenna is 7.6 cm (3 in.) deep. This configuration fits into the probe baseplate.

For the Jupiter parametric studies, the frequency was lowered to 0.86 GHz and the antenna increased in size to 21.8 by 8.84 cm (8.6 by 3.5 in.) and could not be placed on the probe because of structural interference. Another design was selected that is more compact and provides circular polarization with the required pattern.

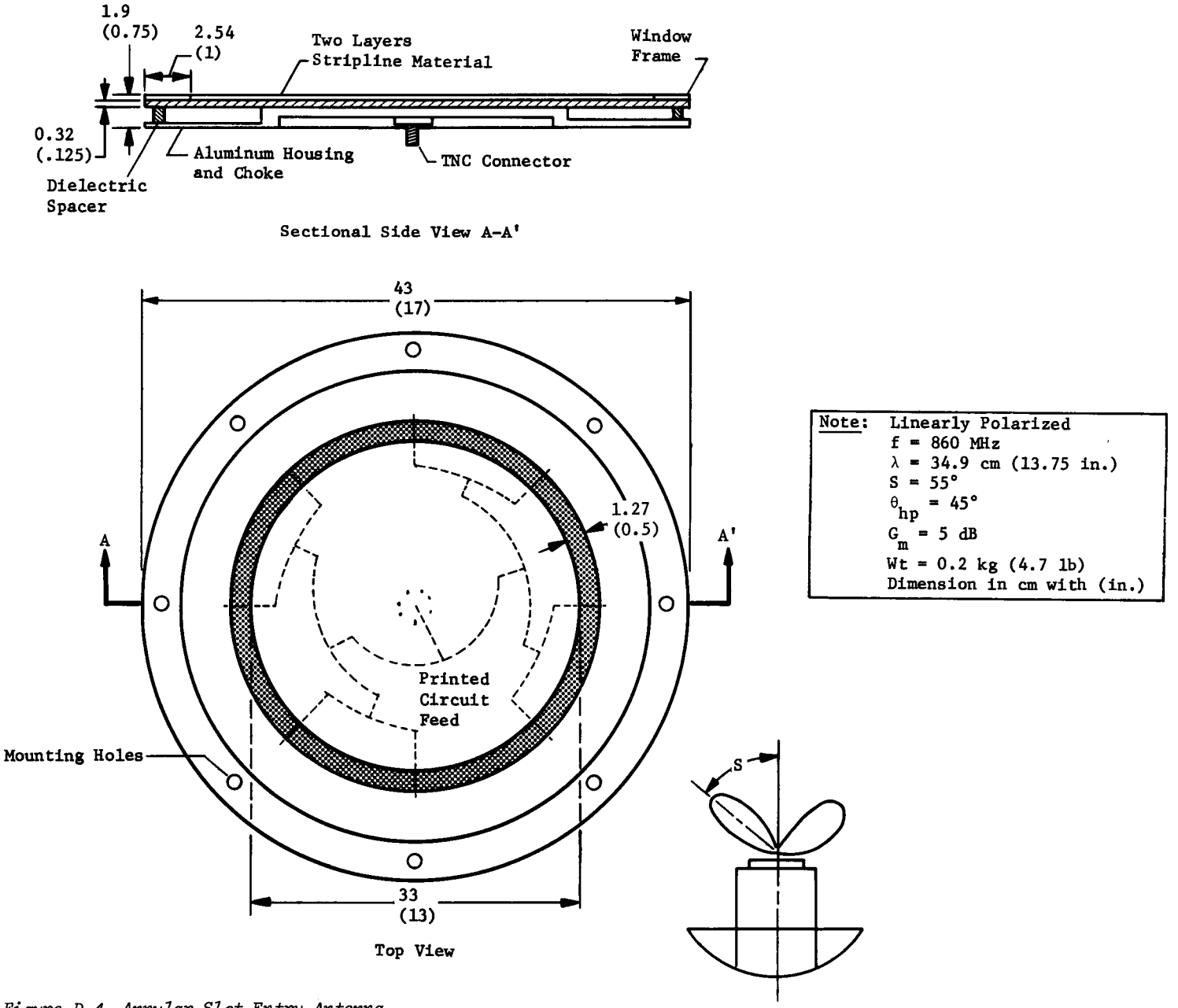


Figure D-4 Annular Slot Entry Antenna

The crossed dipole in a cup was replaced with a modification developed by Martin Marietta for the Viking Program. It is a turnstile design over a flared cone. The Viking model is shown in Figure D-5. The large baseplate seen in the figure is required on the Viking Lander to reduce backlobes and is not needed for the probe mission. For circular polarization, the turnstile arms are unequal by $\lambda/4$. The antenna shown in the figure has linear polarization and operates at 1 GHz. For the probe descent antenna at 0.86 GHz, the same design techniques would be employed as are being used by Martin Marietta to develop this antenna for the Viking Program.

The antenna generates an axial beam pattern with a broad beamwidth and good circularity. A typical pattern is shown in Figure D-6 for linear polarization at 1.75 GHz. The gain/beamwidth relationship is varied by adjusting the dipole flare angle and height above the cone. Design details of the antenna are shown in Figure D-7 for 0.86 GHz and circular polarization. The height and 30° flare angle are preliminary values and are typical for a beamwidth of 100° with a maximum on-axis gain of 5.5 dB.

4. References

D-1 J. D. Krans: *Antennas*. McGraw-Hill, 1950, pp 173 through 216.

D-2 H. Jasik: *Antenna Engineering Handbook*. McGraw-Hill, 1961, pp 8-8 and 27-34 through 27-36.

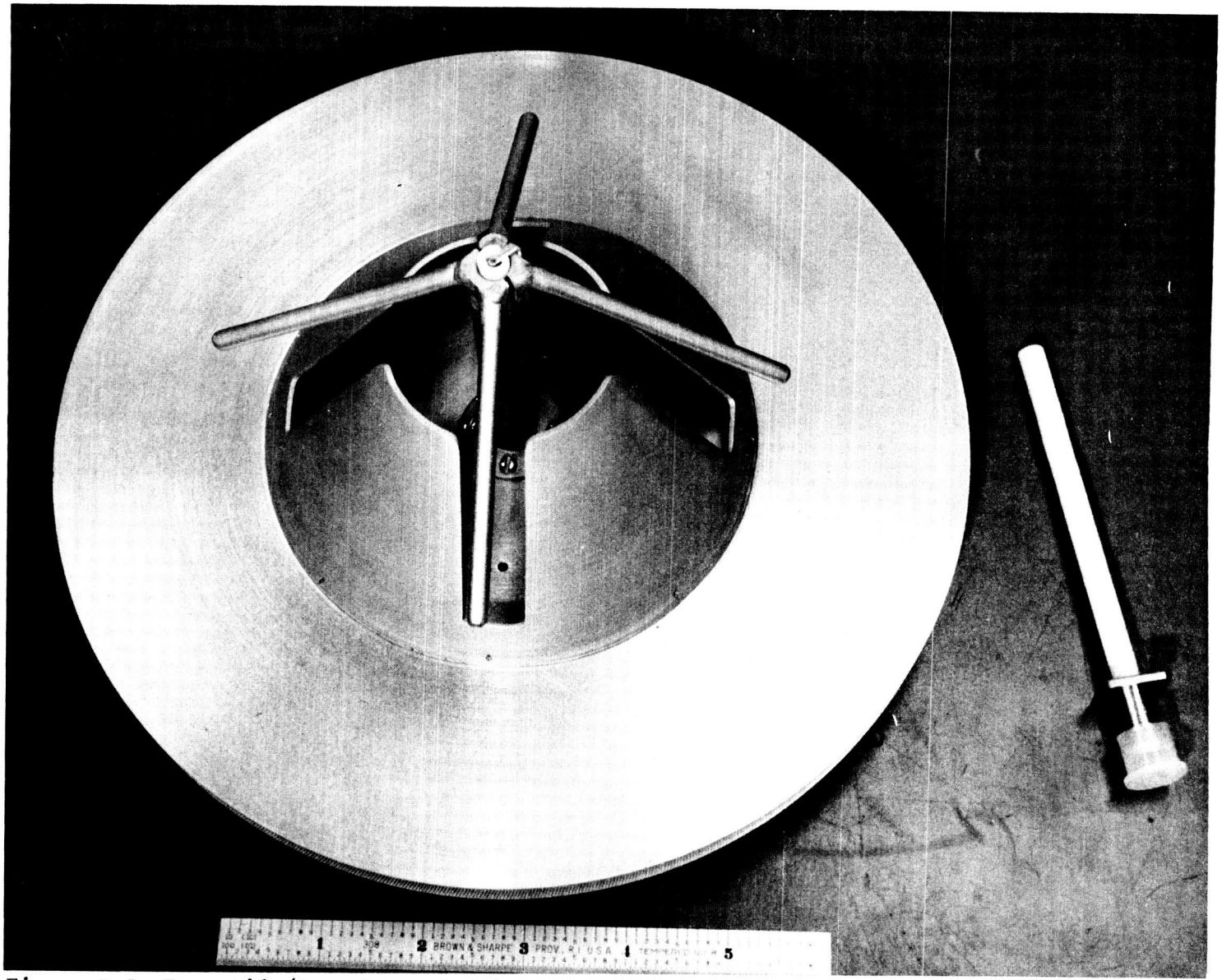
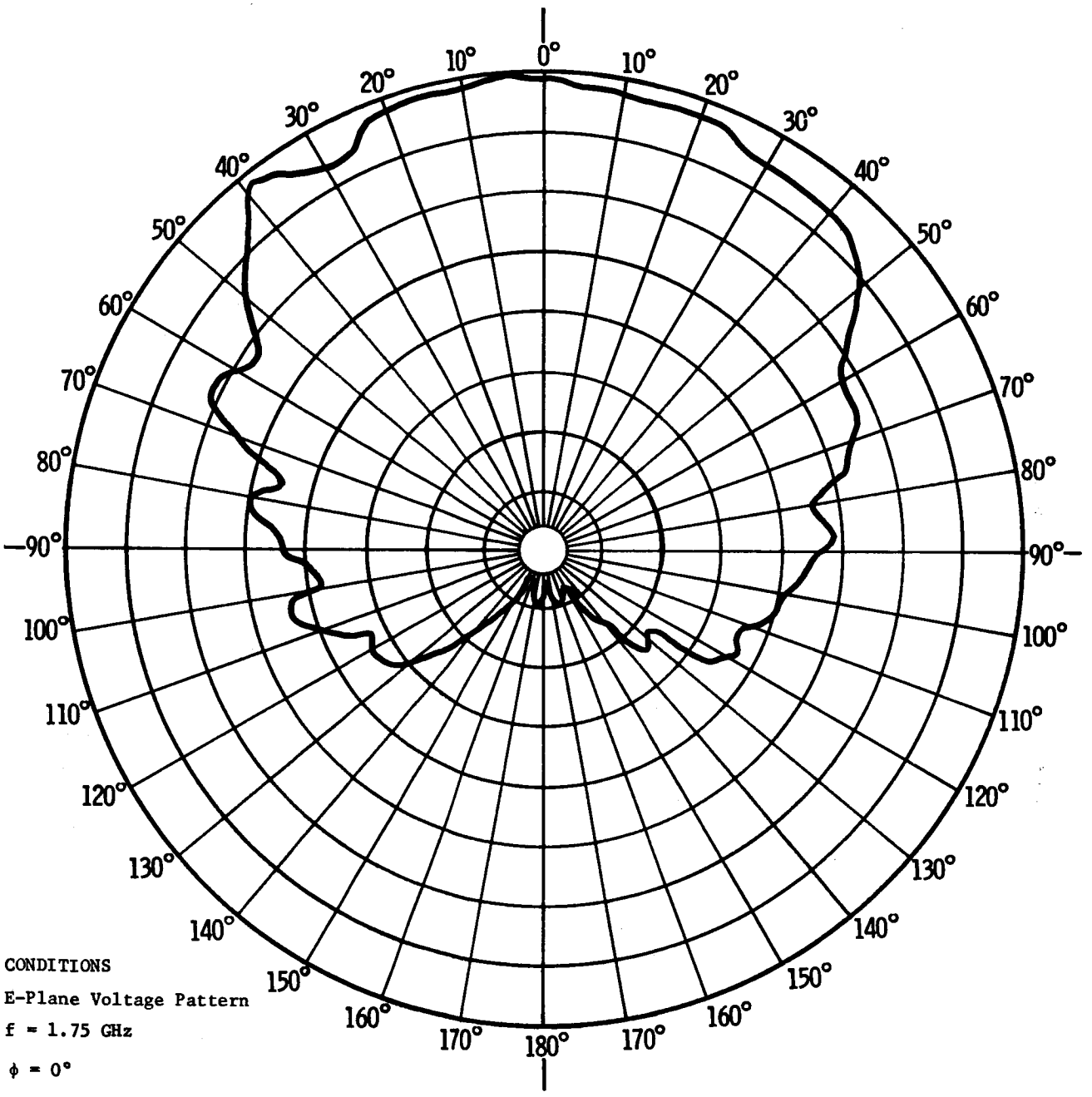


Figure D-5 Turnstile/Cone Descent Antenna



CONDITIONS

E-Plane Voltage Pattern

f = 1.75 GHz

ϕ = 0°

Linear Source

Figure D-6 Turnstile/Cone Antenna Pattern

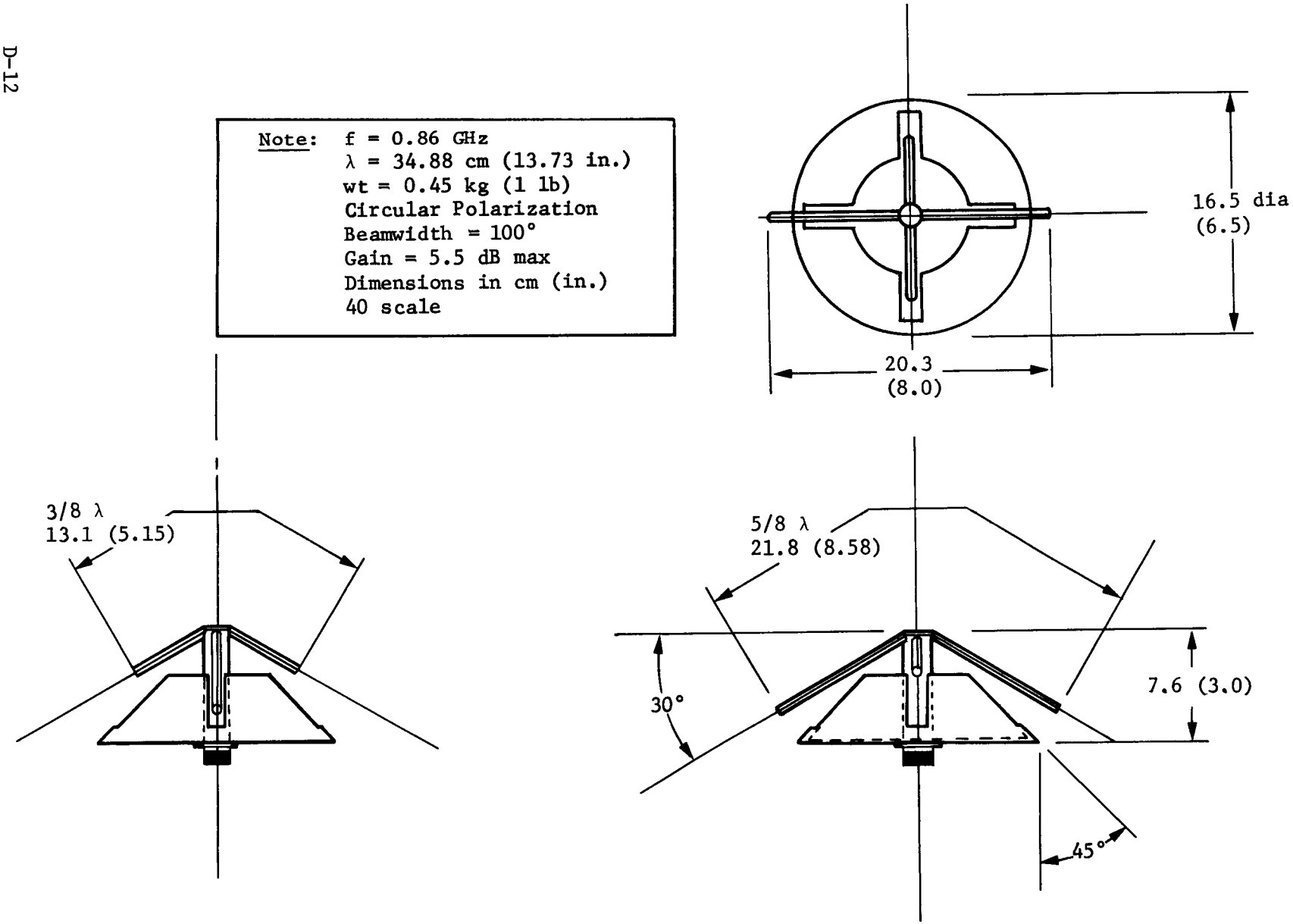


Figure D-7 Survivable Probe Turnstile/Cone Descent Antenna

APPENDIX E

SUMMARY OF PLANETARY ATMOSPHERES AND RELATED CONSTRAINTS

D. Cross
and
R. Fischer

June 8, 1972

SUMMARY OF PLANETARY ATMOSPHERES AND RELATED CONSTRAINTS

The data compiled in this appendix summarizes the pertinent information to be used in modeling the atmospheres of Jupiter, Saturn, Uranus, and Neptune. As far as possible, these data are a duplication of the information provided by References 1, 2, and 3 and were calculated in order to provide a more extensive table (5 km print interval) for use in various analyses. These tables of the atmospheres are presented in Sections B through G. Slight differences arise between the references and the atmospheric tables because of slight variations in the equations which are used to extend the atmosphere from a pressure of one atmosphere at zero altitude. The data presented in the tables given represent the best compromise that yields a good planet atmosphere description. Section G is a summary of these differences.

Section A presents parameters and constants related to the planets and their atmosphers.

A tabular description of the cool-dense Jupiter atmosphere is given in Section B.

Section C presents a tabular description of the nominal Jupiter atmosphere.

The nominal Saturn atmosphere description is tabulated in Section D.

Section E presents a tabular description of the nominal Uranus atmosphere.

A tabular description of the nominal Neptune atmosphere is given in Section F.

Section G presents a comparison of models described in Sections B through F with the models described in the references.

It should be noted that probe entries into the various planetary atmospheres may be at high latitudes, possibly even polar entries. Significant differences in entry radius and entry velocity occur between a polar and an equatorial entry for each of the planets considered, since each planet is oblate. These parameters are defined in Section A.

Two gravitational constants will be used to simulate the probe trajectory. Before entry, an "ephemeris" (μ) will be used to compute the position and velocity as a function of time. After the entry point is reached, a slightly different constant, the "atmospheric" μ will be used to simulate the trajectory within the atmosphere of the planet. The atmospheric μ to be used will be consistent with the specified values for gravitational acceleration (g_o) at the reference radius (r_o). The result of changing the value of μ at entry does not materially affect the descent trajectory of the probe. The two values of μ are given in Section A for each planetary atmosphere.

The molecular weight, grams/mole of the atmospheres of Jupiter and Saturn are a constant value (independent of altitude), and are given in Section A, Table E-2. The molecular weight of the nominal atmospheric models of Uranus and Saturn are variable with a altitude, and are listed in Sections E and F, respectively.

PLANETARY CONSTANTS AND ATMOSPHERIC COMPOSITION PARAMETERS FOR JUPITER, SATURN, URANUS, AND NEPTUNE

This section lists a large number of parameters which are required to define each of the planets physical characteristics and their atmospheres. They are summarized here for reference:

Table E-1 lists the planetary constants of each of the planets (Jupiter, Saturn, Uranus, and Neptune)

Table E-2 lists the compositions and other parameters for model atmospheres of Jupiter, Saturn, Uranus, and Neptune.

Table E-3 summarizes the constants and conversion factors which are related to the study of the planets and their atmospheres.

Entry trajectory studies have indicated that differences between gravitational constant (μ) for planet ephemeris (Table E-1) and (μ) for atmospheres (consistent with given reference radius (r_o) and given reference acceleration of gravity (g_o) makes no significant difference in max g or dynamic pressure values, or altitude of occurrance for $\gamma = -20°$ and greater. Also, at an altitude where Mach = 1.0 occurs, no difference is noted. However, the altitude of Mach = 0.5 shows a noticeable difference of 1.5 km, or 4%.

Table E-1 Planetary Constants

	JUPITER	SATURN	URANUS	NEPTURN	SYMBOL
Equatorial Radius, km (P = 1 atm)	71422 ± 200	59800 ± 350	26468 ± 1000	24857 ± 200	R_o
Polar Radius, km (P = 1 atm)	66815 ± 200	53500 ± 350	25674 ± 1000	24360 ± 200	R_{polar}
Flattening (ε) (Optical)	0.0645	0.10535	0.03 ± 0.03	0.02 ± 0.02	ε
Entry Radius, km (equatorial entry)	71726.9	60291.4	27000 ± 1000	25200 ± 200	Re
Entry Altitude, km	304.9	491.4	532	343	he
(μ_{sun} = 1.32712499 x 10^{11} km^3/sec^2)					
Reciprocal Mass	1047.391	3498.70	22930.0	19260.0	
Gravitational Constant (km^3/sec^2) (used with flyby trajectory calculation)	126707718.8	37932000.	5787723.5	6890576.3	μ
Acceleration of Gravity (go) at Ro (cm/sec^2)	2500 (Nominal) 2700 (Cool) 2300 (Warm)	1050 (Nom)	810 (Nom)	1100 (Nom.)	go
Gravitational Constant (Consistent with reference go and Ro)	127,527,552.1(N) 137,729,756.(C) 117,325,348.(W)	37,548,420.(N) (Ro = 59800)	5,674,449.57(N) (Ro = 26468)	6796574.94(N) (Ro = 24857)	μ_a
Period of Rotation	$9^h55^m29^s73$	$10^h26^m \pm 14^m$	10.816667^h 10^h49^m	12^h43^m	τ
Angular Rotation Rate (Rad/Sec)	1.75853×10^{-4}	1.67×10^{-4}	1.613×10^{-4}	1.372×10^{-4}	ω
Inclination of Orbit Plane to Ecliptic Plane	1.30631°	2.49°	0.77255°	1.77327°	
Inclination of Equatorial Plane to Orbit Plane	3.102°	26.7°	97.884°	29°	
Mean Distance From Sun (AU)	5.202803	9.5388	19.181951	30.057779	
Period of Revolution about Sun (Years)	11.862	29.45772	84.01331	164.79342	
Orbital Velocity (km/s)	13.1	9.7	6.8	5.4	
Orbit Eccentricity	0.048435	0.055682	0.047209	0.008575	
Escape Velocity (km/sec)	59.6 ± 0.6	37	22	25	
Mean Density (g/cm^3)	1.32 ± 0.01	0.69	1.56	2.27	ρ

Table E-2 Compositions and Other Parameters for Model Atmospheres of Jupiter, Saturn, Uranus, and Neptune

PARAMETER		JUPITER COOL MODEL	JUPITER NOMINAL MODEL	JUPITER WARM MODEL	SATURN NOMINAL	URANUS NOMINAL	NEPTUNE NOMINAL
Fractions by mass (or weight)	H_2	0.50696	0.76348	0.87674	0.78514		
	He	0.46000	0.23000	0.11500	0.19373		
	CH_4	0.00857	0.00429	0.00214	0.00444		
	NH_3	0.00219	0.00109	0.00055	0.00113		
	H_2O	0.01601	0.00800	0.00400	0.00828		
	Ne	0.00229	0.00115	0.00057	0.00120		
	Others	0.00398	0.00199	0.00100	0.00244		
Fractions by number (or volume)	H_2	0.68454	0.86578	0.93754	0.88572	0.88572	0.85853
	He	0.31057	0.13214	0.06149	0.11213	0.11000	0.11000
	CH_4	0.00145	0.00062	0.00028	0.00063	0.03000	0.03000
	NH_3	0.00035	0.00015	0.00007	0.00015	0.00015	0.00015
	H_2O	0.00240	0.00102	0.00048	0.00105	0.00100	0.00100
	Ne	0.00031	0.00013	0.00006	0.00013	0.00013	0.00013
	Others	0.00038	0.00016	0.00008	0.00019	0.00019	0.00019
Mean molecular weight, u, grams/mole	MWT	2.70	2.30	2.14	2.27	2.68 to -2.23	2.68 -2.25
Acceleration of Gravity, g, cm/sec^2		2700	2500	2300	1050	810	1100
Effective Temperature, t_o, °K		128	134	140	97	---	---
Troposphere lapse	βo	0.222	0.236	0.259	0.234	0.230	0.23
Rate Parameters	K_1 (°K)	500	500	500	484	484	484
	K_2 (°K)	500	295	324	282	282	282
Correspondence level Temperature, °K		125	125	125	95	84	57
Correspondence level Pressure, atm		0.50	0.30	0.20	0.30	1.0	1.0
Stratosphere temperature, °K		108	113	118			
Stratosphere vertical extent (scale heights)			1.0	1.0	2.0		
Inversion level Temperature, °K		(none)	145	500			
Inversion level pressure, atm		(none)	0.0065	2×10^{-7}			
Ratio of Specific Heats, γ		1.467 (1.45±.15)	1.431 (1.45±.15)	1.418 1.45±.15	1.428	1.447	1.447
Tropopause Temperature, °K		108	113	118	77	54	42
C_{pl}, Cal/mol C°		6.24632	6.60464	6.74651	6.64218	6.4448	6.4448

Table E-3 Constants and Conversion Factors

Heliocentric Gravitational Constant	$2,959122083 \times 10^{-44}$ AU/day^2
Heliocentric Gravitational Constant	$1.32712499 \times 10^{11}$ km^3/S^2
Measure of 1 AU in km	149597893.0 km
Velocity of Light, C	299792.5 km/s
Universal Gravitational Constant, G	6.673×10^{-23}km^{3}sec^{-2}g^{-1}
Feet to Meter	0.3048 (exactly)
Reciprocal Mass (Jupiter)	1047.3908 ± 0.0074
Reciprocal Mass (Saturn)	3499.2 ± 0.4
Reciprocal Mass (Uranus)	22930 ± 6
Reciprocal Mass (Neptune)	19260. ± 100
Universal Gas Constant, R	8.3143 Joules/mole C°
Universal Gas Constant, R	8.3143×10^7 ERGS/mole K°
Universal Gas Constant, R	1.9868 Cal(15°)mole C°
1 Atmosphere of Pressure	1.01325×10^6 dynes/cm^2
1 Atmosphere of Pressure	1.01325×10^5 Newtons/m^2
1 Bar of Pressure	10^6 dynes/cm^2 = 10^5 Newtons/m^2
Ballistic Coefficient of 1 slug/ft^2	157.09 kg/m^2

Section B

Table 1-R356397

JUPIT DATE 01/13/72.

COOL DENSE JUPITER ATMOSPHERE,
MEAN MOLECULAR MASS = 2.700 GRAMS/MOLE
INITIAL PRESSURE =1.013250E+06 DYNES/SQCM AT 71422.00 KM RADIUS
PRINT INTERVAL = 5 KM, GAS CONSTANT = 8.31430000E+07 JOULES/(MOLE.DEG KELVIN
ONE ATMOSPHERE = 1.01325000E+06 DYNES/CM2, MU= 1.37729756E+08 KM3/SEC2
GREF = 2.69999999E-02 KM/SEC2

ALTITUDE IS ABOVE 71422.0 KM RADIUS

RADIUS	ALTITUDE	TEMPERATURE		PRESSURE		DENSITY
KM	KM	KELVIN	FAHREN	DYNE/CM2	ATMOSPHERES	GM/CM3
71288.70	-133.300	405.300	269.870	1.021039E+08	1.007637E+02	8.180948E-03
71293.70	-128.300	395.549	252.319	9.147804E+07	9.028181E+01	7.510246E-03
71298.70	-123.300	385.799	234.768	8.173483E+07	8.066600E+01	6.879933E-03
71303.70	-118.300	376.048	217.217	7.282029E+07	7.186804E+01	6.288495E-03
71308.70	-113.300	366.298	199.666	6.468255E+07	6.383672E+01	5.734438E-03
71313.70	-108.300	356.547	182.115	5.727179E+07	5.652286E+01	5.216239E-03
71318.70	-103.300	346.797	164.564	5.054015E+07	4.987925E+01	4.732597E-03
71323.70	-98.300	337.046	147.013	4.444177E+07	4.386051E+01	4.281934E-03
71328.70	-93.300	327.296	129.462	3.893271E+07	3.842360E+01	3.862891E-03
71333.70	-88.300	317.545	111.911	3.397096E+07	3.352674E+01	3.474086E-03
71334.80	-87.200	315.400	108.050	3.294881E+07	3.251794E+01	3.392470E-03
71337.50	-84.500	310.200	98.690	3.054155E+07	3.014216E+01	3.197329E-03
71338.70	-83.300	307.869	94.495	2.951684E+07	2.913085E+01	3.113448E-03
71343.70	-78.300	298.158	77.014	2.553219E+07	2.519831E+01	2.780867E-03
71347.90	-74.100	290.000	62.330	2.252083E+07	2.222633E+01	2.521880E-03
71348.70	-73.300	288.447	59.534	2.198010E+07	2.169268E+01	2.474585E-03
71353.70	-68.300	278.738	42.058	1.882578E+07	1.857960E+01	2.193285E-03
71358.20	-63.800	270.000	26.330	1.629962E+07	1.608647E+01	1.950432E-03
71358.70	-63.300	269.025	24.576	1.603616E+07	1.582646E+01	1.935732E-03
71363.70	-58.300	259.279	7.032	1.357974E+07	1.340216E+01	1.700835E-03
71368.70	-53.300	249.533	-10.511	1.142684E+07	1.127741E+01	1.487089E-03
71372.00	-50.000	243.100	-22.090	1.015859E+07	1.002575E+01	1.357021E-03
71373.70	-48.300	239.793	-28.043	9.549593E+06	9.424716E+00	1.293263E-03
71378.70	-43.300	230.056	-45.551	7.921832E+06	7.818241E+00	1.118180E-03
71383.70	-38.300	220.339	-63.060	6.518862E+06	6.433617E+00	9.607683E-04
71388.70	-33.300	210.612	-80.568	5.317501E+06	5.247966E+00	8.199034E-04
71393.70	-28.300	200.885	-98.077	4.296083E+06	4.239904E+00	6.944856E-04
71398.70	-23.300	191.158	-115.586	3.434415E+06	3.389504E+00	5.834428E-04
71401.30	-20.700	186.100	-124.690	3.043199E+06	3.003404E+00	5.310337E-04
71403.70	-18.300	181.415	-133.123	2.713730E+06	2.678243E+00	4.857707E-04
71408.70	-13.300	171.655	-150.691	2.116507E+06	2.088928E+00	4.004260E-04
71413.70	-8.300	161.895	-168.260	1.627084E+06	1.605807E+00	3.263742E-04
71415.90	-6.100	157.600	-175.990	1.441965E+06	1.423109E+00	2.971232E-04
71418.70	-3.300	152.144	-185.812	1.230534E+06	1.214442E+00	2.626503E-04
71419.80	-2.200	150.000	-189.670	1.154422E+06	1.139325E+00	2.499259E-04
71422.00	0.	145.800	-197.230	1.013250E+06	1.000000E+00	2.256821E-04
71423.70	1.700	142.513	-203.146	9.137137E+05	9.017654E-01	2.082058E-04
71425.00	3.000	140.000	-207.670	8.428824E+05	8.318603E-01	1.955136E-04
71428.70	6.700	132.792	-220.644	6.644472E+05	6.557584E-01	1.624897E-04
71432.70	10.700	125.000	-234.670	5.061550E+05	4.995362E-01	1.314957E-04
71433.70	11.700	123.053	-238.166	4.716185E+05	4.654512E-01	1.244569E-04
71438.70	16.700	113.348	-255.644	3.254538E+05	3.211980E-01	9.324258E-05
71439.60	17.600	111.600	-258.790	3.034122E+05	2.994446E-01	8.828908E-05
71441.40	19.400	108.000	-265.270	2.628059E+05	2.593693E-01	7.902227E-05
71443.70	21.700	108.000	-265.270	2.180658E+05	2.152142E-01	6.556950E-05
71448.70	26.700	108.000	-265.270	1.453500E+05	1.434493E-01	4.370482E-05
71453.10	31.100	108.000	-265.270	1.017194E+05	1.003892E-01	3.058566E-05

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JUPIT DATE 01/13/72.

COOL DENSE JUPITER ATMOSPHERE,
MEAN MOLECULAR MASS = 2.700 GRAMS/MOLE
INITIAL PRESSURE =1.013250E+06 DYNES/SQCM AT 71422.00 KM RADIUS
PRINT INTERVAL = 5 KM, GAS CONSTANT = 8.31430000E+07 JOULES/(MOLE.DEG KELVIN)
ONE ATMOSPHERE = 1.01325000E+06 DYNES/CM2, MU= 1.37729756E+08 KM3/SEC2
GREF = 2.69999999E-02 KM/SEC2

ALTITUDE IS ABOVE 71422.0 KM RADIUS

RADIUS	ALTITUDE	TEMPERATURE		PRESSURE		DENSITY
KM	KM	KELVIN	FAHREN	DYNE/CM2	ATMOSPHERES	GM/CM3
71453.70	31.700	108.000	-265.270	9.688737E+04	9.562040E-02	2.913275E-05
71458.70	36.700	108.000	-265.270	6.458683E+04	6.374224E-02	1.942040E-05
71463.70	41.700	108.000	-265.270	4.305716E+04	4.249411E-02	1.294672E-05
71468.00	46.000	108.000	-265.270	3.038228E+04	2.998498E-02	9.135549E-06
71468.70	46.700	108.000	-265.270	2.870592E+04	2.833054E-02	8.631490E-06
71473.70	51.700	108.000	-265.270	1.913913E+04	1.888885E-02	5.754883E-06
71478.70	56.700	108.000	-265.270	1.276138E+04	1.259450E-02	3.837177E-06
71481.50	59.500	108.000	-265.270	1.017032E+04	1.003732E-02	3.058080E-06
71483.70	61.700	108.000	-265.270	8.509372E+03	8.398097E-03	2.558656E-06
71488.70	66.700	108.000	-265.270	5.674428E+03	5.600225E-03	1.706225E-06
71493.70	71.700	108.000	-265.270	3.784176E+03	3.734691E-03	1.137852E-06
71496.30	74.300	108.000	-265.270	3.065396E+03	3.025311E-03	9.217241E-07
71498.70	76.700	108.000	-265.270	2.523743E+03	2.490741E-03	7.588561E-07
71503.70	81.700	108.000	-265.270	1.683230E+03	1.661219E-03	5.061251E-07
71508.70	86.700	108.000	-265.270	1.122707E+03	1.108026E-03	3.375832E-07
71509.90	87.900	108.000	-265.270	1.018731E+03	1.005410E-03	3.063191E-07
71513.70	91.700	108.000	-265.270	7.488833E+02	7.390904E-04	2.251793E-07
71518.70	96.700	108.000	-265.270	4.995585E+02	4.930259E-04	1.502106E-07
71523.70	101.700	108.000	-265.270	3.332500E+02	3.289020E-04	1.002069E-07
71524.70	102.700	108.000	-265.270	3.073445E+02	3.033254E-04	9.241442E-08
71528.70	106.700	108.000	-265.270	2.223333E+02	2.194259E-04	6.685268E-08
71533.70	111.700	108.000	-265.270	1.483373E+02	1.463975E-04	4.460307E-08
71538.30	116.300	108.000	-265.270	1.022300E+02	1.008932E-04	3.073921E-08
71538.70	116.700	108.000	-265.270	9.897395E+01	9.767970E-05	2.976016E-08
71543.70	121.700	108.000	-265.270	6.604135E+01	6.517775E-05	1.985776E-08
71548.70	126.700	108.000	-265.270	4.406924E+01	4.349296E-05	1.325104E-08
71553.10	131.100	108.000	-265.270	3.087146E+01	3.046776E-05	9.282639E-09
71553.70	131.700	108.000	-265.270	2.940897E+01	2.902439E-05	8.842887E-09
71558.70	136.700	108.000	-265.270	1.962675E+01	1.937010E-05	5.901505E-09
71563.70	141.700	108.000	-265.270	1.309311E+01	1.292781E-05	3.938729E-09
71566.60	144.600	108.000	-265.270	1.036099E+01	1.022550E-05	3.115411E-09
71568.70	146.700	108.000	-265.270	8.742981E+00	8.628651E-06	2.628899E-09
71573.70	151.700	108.000	-265.270	5.835820E+00	5.759506E-06	1.754754E-09
71578.70	156.700	108.000	-265.270	3.895549E+00	3.844608E-06	1.171340E-09
71581.50	159.500	108.000	-265.270	3.106568E+00	3.065944E-06	9.341039E-10
71583.70	161.700	108.000	-265.270	2.600519E+00	2.566513E-06	7.819418E-10
71588.70	166.700	108.000	-265.270	1.736105E+00	1.713402E-06	5.220238E-10
71593.70	171.700	108.000	-265.270	1.159088E+00	1.143931E-06	3.485224E-10
71595.00	173.000	108.000	-265.270	1.043520E+00	1.029874E-06	3.137727E-10
71598.70	176.700	108.000	-265.270	7.738937E-01	7.637737E-07	2.326996E-10
71603.70	181.700	108.000	-265.270	5.167384E-01	5.099811E-07	1.553764E-10
71608.70	186.700	108.000	-265.270	3.450520E-01	3.405399E-07	1.037526E-10
71609.80	187.800	108.000	-265.270	3.157206E-01	3.115920E-07	9.493301E-11
71613.70	191.700	108.000	-265.270	2.304215E-01	2.274083E-07	6.928470E-11
71614.80	192.800	108.000	-265.270	2.108370E-01	2.080799E-07	6.339588E-11

TABLE 2-R356397

JUPIT DATE 01/13/72.

NOMINAL JUPITER ATMOSPHERE,
MEAN MOLECULAR MASS = 2.300 GRAMS/MOLE
INITIAL PRESSURE =1.013250E+06 DYNES/SQCM AT 71422.00 KM RADIUS
PRINT INTERVAL = 5 KM, GAS CONSTANT = 8.31430000E+07 JOULES/(MOLE.DEG KELVIN)
ONE ATMOSPHERE = 1.01325000E+06 DYNES/CM2, MU= 1.27527552E+08 KM3/SEC2
GREF = 2.50000000E-02 KM/SEC2

ALTITUDE IS ABOVE 71422.0 KM RADIUS

RADIUS	ALTITUDE	TEMPERATURE		PRESSURE		DENSITY
KM	KM	KELVIN	FAHREN	DYNE/CM2	ATMOSPHERES	GM/CM3
71139.20	-282.800	777.000	938.930	1.052698E+08	1.038932E+02	3.747874E-03
71144.20	-277.800	767.087	921.087	1.006233E+08	9.930745E+01	3.628739E-03
71149.20	-272.800	757.175	903.244	9.612599E+07	9.486898E+01	3.511938E-03
71154.20	-267.800	747.262	885.402	9.177499E+07	9.057487E+01	3.397454E-03
71159.20	-262.800	737.349	867.559	8.756732E+07	8.642223E+01	3.285269E-03
71164.20	-257.800	727.437	849.716	8.350007E+07	8.240816E+01	3.175366E-03
71169.20	-252.800	717.524	831.873	7.957032E+07	7.852930E+01	3.067728E-03
71174.20	-247.800	707.611	814.030	7.577521E+07	7.478432E+01	2.962337E-03
71179.20	-242.800	697.699	796.188	7.211187E+07	7.116889E+01	2.859177E-03
71184.20	-237.800	687.786	778.345	6.857748E+07	6.768071E+01	2.758229E-03
71189.20	-232.800	677.873	760.502	6.516922E+07	6.431702E+01	2.659476E-03
71194.20	-227.800	667.961	742.659	6.188431E+07	6.107507E+01	2.562901E-03
71199.20	-222.800	658.048	724.816	5.871998E+07	5.795212E+01	2.468485E-03
71204.20	-217.800	648.135	706.974	5.567351E+07	5.494548E+01	2.376211E-03
71209.20	-212.800	638.223	689.131	5.274216E+07	5.205246E+01	2.286061E-03
71214.20	-207.800	628.310	671.288	4.992325E+07	4.927042E+01	2.198017E-03
71219.20	-202.800	618.397	653.445	4.721412E+07	4.659671E+01	2.112061E-03
71224.20	-197.800	608.485	635.602	4.461211E+07	4.402873E+01	2.028174E-03
71229.20	-192.800	598.572	617.760	4.211461E+07	4.156389E+01	1.946339E-03
71234.20	-187.800	588.659	599.917	3.971902E+07	3.919963E+01	1.866537E-03
71239.20	-182.800	578.747	582.074	3.742278E+07	3.693341E+01	1.788750E-03
71244.20	-177.800	568.834	564.231	3.522332E+07	3.476272E+01	1.712959E-03
71249.20	-172.800	558.921	546.389	3.311814E+07	3.268506E+01	1.639145E-03
71253.70	-168.300	550.000	530.330	3.130201E+07	3.089269E+01	1.574388E-03
71254.20	-167.800	548.923	528.392	3.110472E+07	3.069797E+01	1.567533E-03
71259.20	-162.800	538.155	509.009	2.917884E+07	2.879727E+01	1.499901E-03
71264.20	-157.800	527.387	489.626	2.733711E+07	2.697963E+01	1.433922E-03
71269.20	-152.800	516.619	470.244	2.557744E+07	2.524297E+01	1.369586E-03
71274.20	-147.800	505.851	450.861	2.389776E+07	2.358525E+01	1.306884E-03
71279.20	-142.800	495.082	431.478	2.229598E+07	2.200442E+01	1.245808E-03
71284.20	-137.800	484.314	412.096	2.077006E+07	2.049846E+01	1.186350E-03
71289.20	-132.800	473.546	392.713	1.931795E+07	1.906534E+01	1.128498E-03
71294.20	-127.800	462.778	373.330	1.793762E+07	1.770305E+01	1.072246E-03
71299.20	-122.800	452.010	353.948	1.662705E+07	1.640962E+01	1.017582E-03
71304.20	-117.800	441.242	334.565	1.538423E+07	1.518305E+01	9.644980E-04
71309.20	-112.800	430.473	315.182	1.420717E+07	1.402138E+01	9.129841E-04
71314.20	-107.800	419.705	295.800	1.309388E+07	1.292266E+01	8.630304E-04
71319.20	-102.800	408.937	276.417	1.204241E+07	1.188493E+01	8.146272E-04
71324.20	-97.800	398.169	257.034	1.105079E+07	1.090628E+01	7.677545E-04
71325.30	-96.700	395.800	252.770	1.084047E+07	1.069871E+01	7.576604E-04
71329.20	-92.800	387.774	238.324	1.011742E+07	9.985117E+00	7.217600E-04
71334.20	-87.800	377.485	219.803	9.241021E+06	9.120179E+00	6.772083E-04
71339.20	-82.800	367.196	201.283	8.419539E+06	8.309439E+00	6.342970E-04
71344.20	-77.800	356.907	182.762	7.650913E+06	7.550854E+00	5.930084E-04
71349.20	-72.800	346.617	164.241	6.933108E+06	6.842445E+00	5.533244E-04
71354.20	-67.800	336.328	145.721	6.264111E+06	6.182197E+00	5.152268E-04

TABLE 2-R356397

JUPIT DATE 01/13/72.

NOMINAL JUPITER ATMOSPHERE,
MEAN MOLECULAR MASS = 2.300 GRAMS/MOLE
INITIAL PRESSURE =1.013250E+06 DYNES/SQCM AT 71422.00 KM RADIUS
PRINT INTERVAL = 5 KM, GAS CONSTANT = 8.31430000E+07 JOULES/(MOLE.DEG KELVIN)
ONE ATMOSPHERE = 1.01325000E+06 DYNES/CM2, MU= 1.27527552E+08 KM3/SEC2
GREF = 2.50000000E-02 KM/SEC2

ALTITUDE IS ABOVE 71422.0 KM RADIUS

RADIUS KM	ALTITUDE KM	TEMPERATURE KELVIN	TEMPERATURE FAHREN	PRESSURE DYNE/CM2	PRESSURE ATMOSPHERES	DENSITY GM/CM3
71359.20	-62.800	326.039	127.200	5.641933E+06	5.568155E+00	4.786970E-04
71364.20	-57.800	315.750	108.679	5.064610E+06	4.998382E+00	4.437163E-04
71369.20	-52.800	305.460	90.159	4.530202E+06	4.470962E+00	4.102654E-04
71374.20	-47.800	295.171	71.638	4.036794E+06	3.984006E+00	3.783249E-04
71379.20	-42.800	284.882	53.117	3.582497E+06	3.535650E+00	3.478750E-04
71384.20	-37.800	274.593	34.597	3.165447E+06	3.124053E+00	3.188955E-04
71385.80	-36.200	271.300	28.670	3.039556E+06	2.999809E+00	3.099292E-04
71389.00	-33.000	264.200	15.890	2.798190E+06	2.761599E+00	2.929858E-04
71389.20	-32.800	263.752	15.084	2.783553E+06	2.747153E+00	2.919483E-04
71394.00	-28.000	253.000	-4.270	2.447633E+06	2.415626E+00	2.676258E-04
71394.20	-27.800	252.545	-5.088	2.434266E+06	2.402434E+00	2.666433E-04
71398.40	-23.600	243.000	-22.270	2.164776E+06	2.136467E+00	2.464386E-04
71399.20	-22.800	241.207	-25.498	2.115835E+06	2.088166E+00	2.426577E-04
71404.20	-17.800	230.000	-45.670	1.826809E+06	1.802920E+00	2.197189E-04
71404.20	-17.800	230.000	-45.670	1.826809E+06	1.802920E+00	2.197189E-04
71409.20	-12.800	218.532	-66.312	1.565623E+06	1.545149E+00	1.981865E-04
71414.20	-7.800	207.064	-86.954	1.330694E+06	1.313293E+00	1.777769E-04
71415.10	-6.900	205.000	-90.670	1.291087E+06	1.274204E+00	1.742223E-04
71419.20	-2.800	195.552	-107.676	1.120596E+06	1.105942E+00	1.585216E-04
71422.00	0.	189.100	-119.290	1.013250E+06	1.000000E+00	1.482270E-04
71424.20	2.200	183.919	-128.617	9.338718E+05	9.216598E-01	1.404636E-04
71429.20	7.200	172.143	-149.813	7.689789E+05	7.589231E-01	1.235743E-04
71434.20	12.200	160.367	-171.010	6.245586E+05	6.163914E-01	1.077361E-04
71439.20	17.200	148.591	-192.207	4.992894E+05	4.927604E-01	9.295288E-05
71440.30	18.300	146.000	-196.870	4.741687E+05	4.679681E-01	8.984257E-05
71443.20	21.200	139.000	-209.470	4.119369E+05	4.065501E-01	8.198192E-05
71444.20	22.200	136.586	-213.815	3.917836E+05	3.866604E-01	7.934902E-05
71446.10	24.100	132.000	-222.070	3.552841E+05	3.506382E-01	7.445674E-05
71449.00	27.000	125.000	-234.670	3.039656E+05	2.999908E-01	6.726925E-05
71449.20	27.200	124.524	-235.527	3.006169E+05	2.966858E-01	6.678257E-05
71451.10	29.100	120.000	-243.670	2.700035E+05	2.664727E-01	6.224296E-05
71453.90	31.900	113.000	-256.270	2.286769E+05	2.256866E-01	5.598169E-05
71454.20	32.200	113.000	-256.270	2.245203E+05	2.215843E-01	5.496412E-05
71459.20	37.200	113.000	-256.270	1.653814E+05	1.632188E-01	4.048652E-05
71464.20	42.200	113.000	-256.270	1.218250E+05	1.202320E-01	2.982361E-05
71467.20	45.200	113.000	-256.270	1.014134E+05	1.000872E-01	2.482670E-05
71469.20	47.200	113.000	-256.270	8.974388E+04	8.857033E-02	2.196992E-05
71470.30	48.300	113.000	-256.270	8.390858E+04	8.281133E-02	2.054140E-05
71474.20	52.200	115.645	-251.509	6.629558E+04	6.542865E-02	1.585844E-05
71479.20	57.200	119.036	-245.406	4.939571E+04	4.874978E-02	1.147927E-05
71484.20	62.200	122.426	-239.302	3.711086E+04	3.662557E-02	8.385480E-06
71487.70	65.700	124.800	-235.030	3.052173E+04	3.012261E-02	6.765451E-06
71489.20	67.200	125.814	-233.204	2.810103E+04	2.773356E-02	6.178662E-06
71494.20	72.200	129.195	-227.119	2.143706E+04	2.115674E-02	4.590087E-06
71499.20	77.200	132.576	-221.033	1.646878E+04	1.625342E-02	3.436354E-06
71504.20	82.200	135.957	-214.947	1.273669E+04	1.257014E-02	2.591533E-06
71508.70	86.700	139.000	-209.470	1.016186E+04	1.002898E-02	2.022370E-06

TABLE 2-R356397

JUPIT DATE 01/13/72.

NOMINAL JUPITER ATMOSPHERE,
MEAN MOLECULAR MASS = 2.300 GRAMS/MOLE
INITIAL PRESSURE =1.013250E+06 DYNES/SQCM AT 71422.00 KM RADIUS
PRINT INTERVAL = 5 KM, GAS CONSTANT = 8.31430000E+07 JOULES/(MOLE.DEG KELVIN)
ONE ATMOSPHERE = 1.01325000E+06 DYNES/CM2, MU= 1.27527552E+08 KM3/SEC2
GREF = 2.50000000E-02 KM/SEC2

ALTITUDE IS ABOVE 71422.0 KM RADIUS

RADIUS	ALTITUDE	TEMPERATURE		PRESSURE		DENSITY
KM	KM	KELVIN	FAHREN	DYNE/CM2	ATMOSPHERES	GM/CM3
71509.20	87.200	139.341	-208.856	9.913083E+03	9.783452E-03	1.968032E-06
71514.20	92.200	142.750	-202.720	7.762435E+03	7.660928E-03	1.504264E-06
71517.50	95.500	145.000	-198.670	6.626550E+03	6.539896E-03	1.264217E-06
71519.20	97.200	145.000	-198.670	6.111797E+03	6.031875E-03	1.166012E-06
71524.20	102.200	145.000	-198.670	4.818244E+03	4.755237E-03	9.192273E-07
71529.20	107.200	145.000	-198.670	3.798596E+03	3.748922E-03	7.246982E-07
71533.70	111.700	145.000	-198.670	3.066876E+03	3.026772E-03	5.851004E-07
71534.20	112.200	145.000	-198.670	2.994827E+03	2.955665E-03	5.713549E-07
71539.20	117.200	145.000	-198.670	2.361212E+03	2.330335E-03	4.504734E-07
71544.20	122.200	145.000	-198.670	1.861712E+03	1.837367E-03	3.551785E-07
71549.20	127.200	145.000	-198.670	1.467927E+03	1.448732E-03	2.800520E-07
71554.20	132.200	145.000	-198.670	1.157473E+03	1.142337E-03	2.208234E-07
71556.80	134.800	145.000	-198.670	1.022954E+03	1.009577E-03	1.951597E-07
71559.20	137.200	145.000	-198.670	9.127081E+02	9.007728E-04	1.741270E-07
71564.20	142.200	145.000	-198.670	7.197260E+02	7.103143E-04	1.373097E-07
71569.20	147.200	145.000	-198.670	5.675667E+02	5.601447E-04	1.082807E-07
71574.20	152.200	145.000	-198.670	4.475906E+02	4.417376E-04	8.539160E-08
71579.20	157.200	145.000	-198.670	3.529877E+02	3.483717E-04	6.734319E-08
71582.00	160.000	145.000	-198.670	3.090422E+02	3.050009E-04	5.895925E-08
71584.20	162.200	145.000	-198.670	2.783892E+02	2.747488E-04	5.311126E-08
71589.20	167.200	145.000	-198.670	2.195633E+02	2.166921E-04	4.188941E-08
71594.20	172.200	145.000	-198.670	1.731735E+02	1.709090E-04	3.303814E-08
71599.20	177.200	145.000	-198.670	1.365896E+02	1.348034E-04	2.605864E-08
71604.20	182.200	145.000	-198.670	1.077378E+02	1.063289E-04	2.055428E-08
71605.10	183.100	145.000	-198.670	1.032335E+02	1.018836E-04	1.959495E-08
71609.20	187.200	145.000	-198.670	8.498319E+01	8.387189E-05	1.621314E-08
71614.20	192.200	145.000	-198.670	6.703666E+01	6.616003E-05	1.278929E-08
71619.20	197.200	145.000	-198.670	5.288177E+01	5.219025E-05	1.008882E-08
71624.20	202.200	145.000	-198.670	4.171710E+01	4.117157E-05	7.958812E-09
71629.20	207.200	145.000	-198.670	3.291065E+01	3.248029E-05	6.278713E-09
71630.30	208.300	145.000	-198.670	3.123801E+01	3.082952E-05	5.959606E-09
71634.20	212.200	145.000	-198.670	2.596410E+01	2.562458E-05	4.953447E-09
71639.20	217.200	145.000	-198.670	2.048446E+01	2.021659E-05	3.908037E-09
71644.20	222.200	145.000	-198.670	1.616181E+01	1.595047E-05	3.083360E-09
71649.20	227.200	145.000	-198.670	1.275176E+01	1.258500E-05	2.432787E-09
71653.40	231.400	145.000	-198.670	1.045029E+01	1.031363E-05	1.993712E-09
71654.20	232.200	145.000	-198.670	1.006154E+01	9.929964E-06	1.919546E-09
71659.20	237.200	145.000	-198.670	7.939130E+00	7.835313E-06	1.514632E-09
71664.20	242.200	145.000	-198.670	6.264637E+00	6.182716E-06	1.195171E-09
71669.20	247.200	145.000	-198.670	4.943486E+00	4.878841E-06	9.431211E-10
71674.20	252.200	145.000	-198.670	3.901081E+00	3.850068E-06	7.442505E-10
71678.60	256.600	145.000	-198.670	3.167309E+00	3.125891E-06	6.042610E-10
71679.20	257.200	145.000	-198.670	3.078584E+00	3.038327E-06	5.873341E-10
71684.20	262.200	145.000	-198.670	2.429582E+00	2.397811E-06	4.635170E-10
71689.20	267.200	145.000	-198.670	1.917460E+00	1.892386E-06	3.658140E-10
71694.20	272.200	145.000	-198.670	1.513336E+00	1.493546E-06	2.887151E-10

TABLE 2-R356397

JUPIT DATE 01/13/72.

NOMINAL JUPITER ATMOSPHERE,
MEAN MOLECULAR MASS = 2.300 GRAMS/MOLE
INITIAL PRESSURE =1.013250E+06 DYNES/SQCM AT 71422.00 KM RADIUS
PRINT INTERVAL = 5 KM, GAS CONSTANT = 8.31430000E+07 JOULES/(MOLE.DEG KELVIN)
ONE ATMOSPHERE = 1.01325000E+06 DYNES/CM2, MU= 1.27527552E+08 KM3/SEC2
GREF = 2.50000000E-02 KM/SEC2

ALTITUDE IS ABOVE 71422.0 KM RADIUS

RADIUS	ALTITUDE	TEMPERATURE		PRESSURE		DENSITY
KM	KM	KELVIN	FAHREN	DYNE/CM2	ATMOSPHERES	GM/CM3
71699.20	277.200	145.000	-198.670	1.194425E+00	1.178805E-06	2.278730E-10
71701.70	279.700	145.000	-198.670	1.061148E+00	1.047271E-06	2.024464E-10
71704.20	282.200	145.000	-198.670	9.427499E-01	9.304218E-07	1.798584E-10
71709.20	287.200	145.000	-198.670	7.441296E-01	7.343988E-07	1.419655E-10
71714.20	292.200	145.000	-198.670	5.873744E-01	5.796934E-07	1.120596E-10
71719.20	297.200	145.000	-198.670	4.636558E-01	4.575927E-07	8.845653E-11
71724.20	302.200	145.000	-198.670	3.660082E-01	3.612220E-07	6.982725E-11
71726.90	304.900	145.000	-198.670	3.221336E-01	3.179212E-07	6.145684E-11
71729.20	307.200	145.000	-198.670	2.889350E-01	2.851567E-07	5.512319E-11
71734.20	312.200	145.000	-198.670	2.280993E-01	2.251165E-07	4.351691E-11
71735.40	313.400	145.000	-198.670	2.155181E-01	2.126998E-07	4.111666E-11

TABLE 4-R356397

SATURN DATE 01/13/72.
NOMINAL SATURN ATMOSPHERE,
MEAN MOLECULAR MASS = 2.270 GRAMS/MOLE
INITIAL PRESSURE =1.013250E+06 DYNES/SQCM AT 59800.00 KM RADIUS
PRINT INTERVAL = 10 KM, GAS CONSTANT = 8.31430000E+07 JOULES/(MOLE.DEG KELVIN
ONE ATMOSPHERE = 1.01325000E+06 DYNES/CM2, MU= 3.75484200E+07 KM3/SEC2
GREF = 1.05000000E-02 KM/SEC2

ALTITUDE IS ABOVE 59800.0 KM RADIUS

RADIUS KM	ALTITUDE KM	TEMPERATURE KELVIN	TEMPERATURE FAHREN	PRESSURE DYNE/CM2	PRESSURE ATMOSPHERES	DENSITY GM/CM3
59264.00	-536.000	617.800	652.370	1.053257E+08	1.039484E+02	4.654647E-03
59274.00	-526.000	609.412	637.271	1.004336E+08	9.912022E+01	4.499540E-03
59284.00	-516.000	601.024	622.173	9.570707E+07	9.445554E+01	4.347630E-03
59294.00	-506.000	592.636	607.074	9.114275E+07	8.995090E+01	4.198890E-03
59304.00	-496.000	584.247	591.975	8.673711E+07	8.560287E+01	4.053295E-03
59314.00	-486.000	575.859	576.877	8.248671E+07	8.140805E+01	3.910819E-03
59324.00	-476.000	567.471	561.778	7.838812E+07	7.736306E+01	3.771435E-03
59334.00	-466.000	559.083	546.680	7.443797E+07	7.346456E+01	3.635116E-03
59344.00	-456.000	550.695	531.581	7.063288E+07	6.970924E+01	3.501838E-03
59354.00	-446.000	542.307	516.482	6.696956E+07	6.609381E+01	3.371572E-03
59364.00	-436.000	533.919	501.384	6.344468E+07	6.261504E+01	3.244294E-03
59374.00	-426.000	525.531	486.285	6.005501E+07	5.926969E+01	3.119977E-03
59384.00	-416.000	517.142	471.186	5.679731E+07	5.605458E+01	2.998594E-03
59394.00	-406.000	508.754	456.088	5.366837E+07	5.296656E+01	2.880119E-03
59404.00	-396.000	500.366	440.989	5.066503E+07	5.000250E+01	2.764525E-03
59414.00	-386.000	491.978	425.891	4.778417E+07	4.715931E+01	2.651786E-03
59424.00	-376.000	483.590	410.792	4.502266E+07	4.443391E+01	2.541874E-03
59434.00	-366.000	475.202	395.693	4.237745E+07	4.182329E+01	2.434764E-03
59444.00	-356.000	466.814	380.595	3.984548E+07	3.932443E+01	2.330428E-03
59454.00	-346.000	458.426	365.496	3.742376E+07	3.693438E+01	2.228839E-03
59464.00	-336.000	450.037	350.397	3.510930E+07	3.465018E+01	2.129971E-03
59474.00	-326.000	441.649	335.299	3.289915E+07	3.246894E+01	2.033796E-03
59483.00	-317.000	434.100	321.710	3.099680E+07	3.059147E+01	1.949518E-03
59484.00	-316.000	433.222	320.130	3.079040E+07	3.038776E+01	1.940460E-03
59494.00	-306.000	424.445	304.331	2.877912E+07	2.840278E+01	1.851213E-03
59504.00	-296.000	415.667	288.531	2.686189E+07	2.651062E+01	1.764374E-03
59514.00	-286.000	406.890	272.732	2.503611E+07	2.470872E+01	1.679925E-03
59524.00	-276.000	398.113	256.933	2.329920E+07	2.299452E+01	1.597847E-03
59534.00	-266.000	389.335	241.134	2.164859E+07	2.136550E+01	1.518120E-03
59544.00	-256.000	380.558	225.334	2.008175E+07	1.981915E+01	1.440725E-03
59554.00	-246.000	371.781	209.535	1.859617E+07	1.835299E+01	1.365642E-03
59564.00	-236.000	363.003	193.736	1.718934E+07	1.696456E+01	1.292852E-03
59574.00	-226.000	354.226	177.936	1.585880E+07	1.565142E+01	1.222335E-03
59584.00	-216.000	345.448	162.137	1.460211E+07	1.441116E+01	1.154071E-03
59594.00	-206.000	336.671	146.338	1.341684E+07	1.324140E+01	1.088040E-03
59604.00	-196.000	327.894	130.539	1.230061E+07	1.213976E+01	1.024221E-03
59614.00	-186.000	319.116	114.739	1.125102E+07	1.110390E+01	9.625943E-04
59624.00	-176.000	310.339	98.940	1.026575E+07	1.013150E+01	9.031388E-04
59624.50	-175.500	309.900	98.150	1.021813E+07	1.008451E+01	9.002227E-04
59634.00	-166.000	301.264	82.605	9.342036E+06	9.219873E+00	8.466326E-04
59644.00	-156.000	292.173	66.241	8.477192E+06	8.366338E+00	7.921593E-04
59654.00	-146.000	283.082	49.877	7.669082E+06	7.568795E+00	7.396590E-04
59661.90	-138.100	275.900	36.950	7.069400E+06	6.976955E+00	6.995697E-04
59664.00	-136.000	273.971	33.478	6.915589E+06	6.825155E+00	6.891667E-04
59674.00	-126.000	264.787	16.946	6.214464E+06	6.133199E+00	6.407777E-04
59684.00	-116.000	255.602	.414	5.563591E+06	5.490838E+00	5.942789E-04
59690.10	-109.900	250.000	-9.670	5.190372E+06	5.122499E+00	5.668376E-04

TABLE 4-R356397

SATURN DATE 01/13/72.

NOMINAL SATURN ATMOSPHERE,

MEAN MOLECULAR MASS = 2.270 GRAMS/MOLE

INITIAL PRESSURE =1.013250E+06 DYNES/SQCM AT 59800.00 KM RADIUS

PRINT INTERVAL = 10 KM, GAS CONSTANT = 8.31430000E+07 JOULES/(MOLE.DEG KELVIN)

ONE ATMOSPHERE = 1.01325000E+06 DYNES/CM2, MU= 3.75484200E+07 KM3/SEC2

GREF = 1.05000000E-02 KM/SEC2

ALTITUDE IS ABOVE 59800.0 KM RADIUS

RADIUS KM	ALTITUDE KM	TEMPERATURE KELVIN	TEMPERATURE FAHREN	PRESSURE DYNE/CM2	PRESSURE ATMOSPHERES	DENSITY GM/CM3
59694.00	-106.000	246.372	-16.200	4.960931E+06	4.896058E+00	5.497584E-04
59704.00	-96.000	237.070	-32.944	4.404293E+06	4.346699E+00	5.072245E-04
59711.60	-88.400	230.000	-45.670	4.010801E+06	3.958353E+00	4.761057E-04
59714.00	-86.000	227.703	-49.804	3.891672E+06	3.840781E+00	4.666238E-04
59724.00	-76.000	218.134	-67.029	3.420783E+06	3.376050E+00	4.281563E-04
59732.50	-67.500	210.000	-81.670	3.051861E+06	3.011953E+00	3.967762E-04
59734.00	-66.000	208.563	-84.256	2.989657E+06	2.950562E+00	3.913664E-04
59744.00	-56.000	198.985	-101.496	2.596496E+06	2.562542E+00	3.562597E-04
59754.00	-46.000	189.407	-118.737	2.239516E+06	2.210231E+00	3.228177E-04
59764.00	-36.000	179.830	-135.977	1.916945E+06	1.891877E+00	2.910373E-04
59774.00	-26.000	170.252	-153.217	1.627013E+06	1.605737E+00	2.609155E-04
59784.00	-16.000	160.674	-170.457	1.367958E+06	1.350070E+00	2.324493E-04
59794.00	-6.000	151.096	-187.698	1.138023E+06	1.123141E+00	2.056358E-04
59794.10	-5.900	151.000	-187.870	1.135865E+06	1.121011E+00	2.053760E-04
59800.00	0.	145.200	-198.310	1.013250E+06	1.000000E+00	1.905242E-04
59804.00	4.000	141.226	-205.463	9.352829E+05	9.230525E-01	1.808123E-04
59814.00	14.000	131.292	-223.345	7.578077E+05	7.478981E-01	1.575878E-04
59815.30	15.300	130.000	-225.670	7.365062E+05	7.268751E-01	1.546797E-04
59824.00	24.000	121.174	-241.557	6.038788E+05	5.959821E-01	1.360533E-04
59834.00	34.000	111.029	-259.818	4.717923E+05	4.656228E-01	1.160151E-04
59844.00	44.000	100.884	-278.079	3.600081E+05	3.553004E-01	9.742938E-05
59849.80	49.800	95.000	-288.670	3.038629E+05	2.998894E-01	8.732815E-05
59854.00	54.000	90.630	-296.536	2.669479E+05	2.634571E-01	8.041822E-05
59864.00	64.000	80.225	-315.264	1.908953E+05	1.883991E-01	6.496559E-05
59867.10	67.100	77.000	-321.070	1.705298E+05	1.682998E-01	6.046579E-05
59874.00	74.000	77.000	-321.070	1.319766E+05	1.302508E-01	4.679575E-05
59881.10	81.100	77.000	-321.070	1.013898E+05	1.000640E-01	3.595040E-05
59884.00	84.000	77.000	-321.070	9.104025E+04	8.984974E-02	3.228069E-05
59894.00	94.000	77.000	-321.070	6.280926E+04	6.198792E-02	2.227066E-05
59904.00	104.000	77.000	-321.070	4.333789E+04	4.277117E-02	1.536658E-05
59913.40	113.400	77.000	-321.070	3.057949E+04	3.017961E-02	1.084276E-05
59914.00	114.000	77.000	-321.070	2.990650E+04	2.951542E-02	1.060413E-05
59920.80	120.800	77.000	-321.070	2.324058E+04	2.293666E-02	8.240552E-06
59924.00	124.000	77.329	-320.479	2.064557E+04	2.037559E-02	7.289321E-06
59934.00	134.000	78.355	-318.630	1.430775E+04	1.412065E-02	4.985431E-06
59943.20	143.200	79.300	-316.930	1.025498E+04	1.012088E-02	3.530709E-06
59944.00	144.000	79.380	-316.786	9.964174E+03	9.833875E-03	3.427139E-06
59954.00	154.000	80.377	-314.992	6.971871E+03	6.880702E-03	2.368201E-06
59964.00	164.000	81.374	-313.197	4.900277E+03	4.836197E-03	1.644128E-06
59974.00	174.000	82.371	-311.402	3.459451E+03	3.414213E-03	1.146656E-06
59977.30	177.300	82.700	-310.810	3.086876E+03	3.046510E-03	1.019093E-06
59984.00	184.000	83.385	-309.578	2.452861E+03	2.420785E-03	8.031332E-07
59994.00	194.000	84.406	-307.739	1.746642E+03	1.723802E-03	5.649757E-07
60004.00	204.000	85.428	-305.900	1.248987E+03	1.232654E-03	3.991706E-07
60009.60	209.600	86.000	-304.870	1.036994E+03	1.023433E-03	3.292136E-07
60014.00	214.000	86.441	-304.076	8.967849E+02	8.850579E-04	2.832486E-07

TABLE 4-R356397

SATURN DATE 01/13/72.

NOMINAL SATURN ATMOSPHERE,
MEAN MOLECULAR MASS = 2.270 GRAMS/MOLE
INITIAL PRESSURE =1.013250E+06 DYNES/SQCM AT 59800.00 KM RADIUS
PRINT INTERVAL = 10 KM, GAS CONSTANT = 8.31430000E+07 JOULES/(MOLE.DEG KELVIN
ONE ATMOSPHERE = 1.01325000E+06 DYNES/CM2, MU= 3.75484200E+07 KM3/SEC2
GREF = 1.05000000E-02 KM/SEC2

ALTITUDE IS ABOVE 59800.0 KM RADIUS

RADIUS	ALTITUDE	TEMPERATURE		PRESSURE		DENSITY
KM	KM	KELVIN	FAHREN	DYNE/CM2	ATMOSPHERES	GM/CM3
60024.00	224.000	87.444	-302.271	6.464431E+02	6.379897E-04	2.018371E-07
60034.00	234.000	88.447	-300.466	4.677782E+02	4.616612E-04	1.443973E-07
60044.00	244.000	89.449	-298.661	3.397659E+02	3.353228E-04	1.037058E-07
60046.50	246.500	89.700	-298.210	3.138449E+02	3.097408E-04	9.552627E-08
60054.00	254.000	90.469	-296.825	2.476983E+02	2.444592E-04	7.475190E-08
60064.00	264.000	91.495	-294.979	1.812415E+02	1.788714E-04	5.408303E-08
60074.00	274.000	92.521	-293.133	1.330912E+02	1.313508E-04	3.927457E-08
60081.60	281.600	93.300	-291.730	1.054987E+02	1.041191E-04	3.087206E-08
60084.00	284.000	93.540	-291.298	9.807594E+01	9.679343E-05	2.862631E-08
60094.00	294.000	94.540	-289.498	7.251700E+01	7.156871E-05	2.094230E-08
60104.00	304.000	95.540	-287.698	5.379476E+01	5.309130E-05	1.537287E-08
60114.00	314.000	96.540	-285.898	4.003441E+01	3.951089E-05	1.132208E-08
60121.60	321.600	97.300	-284.530	3.205047E+01	3.163136E-05	8.993355E-09
60124.00	324.000	97.540	-284.098	2.988761E+01	2.949678E-05	8.365823E-09
60134.00	334.000	98.540	-282.298	2.238132E+01	2.208865E-05	6.201166E-09
60144.00	344.000	99.540	-280.498	1.681085E+01	1.659102E-05	4.610970E-09
60154.00	354.000	100.540	-278.698	1.266419E+01	1.249858E-05	3.439050E-09
60159.60	359.600	101.100	-277.690	1.082035E+01	1.067886E-05	2.922068E-09
60164.00	364.000	101.546	-276.887	9.568069E+00	9.442950E-06	2.572535E-09
60174.00	374.000	102.560	-275.062	7.249672E+00	7.154870E-06	1.929927E-09
60184.00	384.000	103.574	-273.237	5.508552E+00	5.436518E-06	1.452071E-09
60194.00	394.000	104.588	-271.412	4.197181E+00	4.142295E-06	1.095665E-09
60203.00	403.000	105.500	-269.770	3.293773E+00	3.250701E-06	8.523960E-10
60204.00	404.000	105.602	-269.587	3.206682E+00	3.164749E-06	8.290584E-10
60214.00	414.000	106.619	-267.756	2.456470E+00	2.424348E-06	6.290404E-10
60224.00	424.000	107.636	-265.926	1.886705E+00	1.862033E-06	4.785731E-10
60234.00	434.000	108.653	-264.095	1.452821E+00	1.433822E-06	3.650667E-10
60244.00	444.000	109.669	-262.265	1.121539E+00	1.106873E-06	2.792087E-10
60244.30	444.300	109.700	-262.210	1.112908E+00	1.098355E-06	2.769829E-10
60254.00	454.000	110.689	-260.431	8.679458E-01	8.565959E-07	2.140869E-10
60264.00	464.000	111.708	-258.596	6.733292E-01	6.645243E-07	1.645678E-10
60274.00	474.000	112.727	-256.762	5.236005E-01	5.167535E-07	1.268157E-10
60284.00	484.000	113.746	-254.927	4.081234E-01	4.027865E-07	9.796165E-11
60291.40	491.400	114.500	-253.570	3.399089E-01	3.354640E-07	8.105077E-11
60294.00	494.000	114.762	-253.099	3.188478E-01	3.146783E-07	7.585538E-11
60304.00	504.000	115.768	-251.287	2.496606E-01	2.463958E-07	5.887893E-11
60314.00	514.000	116.775	-249.475	1.959167E-01	1.933547E-07	4.580586E-11
60324.00	524.000	117.782	-247.663	1.540746E-01	1.520598E-07	3.571517E-11
60334.00	534.000	118.789	-245.851	1.214264E-01	1.198385E-07	2.790863E-11
60336.10	536.100	119.000	-245.470	1.155343E-01	1.140235E-07	2.650722E-11

TABLE 5-R356397

URANUS DATE 01/13/72.
NOMINAL URANUS ATMOSPHERE,
MEAN MOLECULAR MASS = 2.680 GRAMS/MOLE
INITIAL PRESSURE =1.013250E+06 DYNES/SQCM AT 26468.00 KM RADIUS
PRINT INTERVAL = 5 KM, GAS CONSTANT = 8.31430000E+07 JOULES/(MOLE.DEG KELVIN)
ONE ATMOSPHERE = 1.01325000E+06 DYNES/CM2, MU= 5.67444957E+06 KM3/SEC2
GREF = 8.09993416E-03 KM/SEC2

ALTITUDE IS ABOVE 26468.0 KM RADIUS

RADIUS KM	ALTITUDE KM	TEMPERATURE KELVIN	TEMPERATURE FAHREN	PRESSURE DYNE/CM2	PRESSURE ATMOSPHERES	DENSITY GM/CM3
26112.10	-355.900	382.300	228.470	1.115883E+08	1.101291E+02	9.404984E-03
26117.10	-350.900	376.033	217.190	1.077119E+08	1.063033E+02	9.230296E-03
26122.10	-345.900	369.767	205.910	1.039095E+08	1.025507E+02	9.056109E-03
26127.10	-340.900	363.500	194.631	1.001808E+08	9.887079E+01	8.882425E-03
26132.10	-335.900	357.234	183.351	9.652569E+07	9.526345E+01	8.709249E-03
26137.10	-330.900	350.967	172.071	9.294379E+07	9.172839E+01	8.536581E-03
26142.10	-325.900	344.701	160.791	8.943484E+07	8.826533E+01	8.364426E-03
26147.10	-320.900	338.434	149.511	8.599859E+07	8.487401E+01	8.192786E-03
26152.10	-315.900	332.168	138.232	8.263476E+07	8.155417E+01	8.021665E-03
26157.10	-310.900	325.901	126.952	7.934308E+07	7.830554E+01	7.851065E-03
26162.10	-305.900	319.634	115.672	7.612329E+07	7.512784E+01	7.680990E-03
26167.10	-300.900	313.368	104.392	7.297510E+07	7.202082E+01	7.511444E-03
26172.10	-295.900	307.101	93.112	6.989825E+07	6.898420E+01	7.342430E-03
26172.50	-295.500	306.600	92.210	6.965517E+07	6.874431E+01	7.328932E-03
26177.10	-290.900	305.539	90.300	6.691352E+07	6.603851E+01	7.064732E-03
26182.10	-285.900	304.386	88.225	6.404668E+07	6.320915E+01	6.787482E-03
26187.10	-280.900	303.233	86.149	6.129357E+07	6.049205E+01	6.520239E-03
26192.10	-275.900	302.080	84.074	5.865005E+07	5.788310E+01	6.262671E-03
26197.10	-270.900	300.927	81.998	5.611210E+07	5.537834E+01	6.014460E-03
26202.10	-265.900	299.774	79.923	5.367583E+07	5.297393E+01	5.775293E-03
26207.10	-260.900	298.621	77.847	5.133750E+07	5.066617E+01	5.544871E-03
26212.10	-255.900	297.468	75.772	4.909347E+07	4.845148E+01	5.322900E-03
26217.10	-250.900	296.315	73.696	4.694024E+07	4.632641E+01	5.109098E-03
26222.10	-245.900	295.161	71.621	4.487443E+07	4.428762E+01	4.903189E-03
26222.80	-245.200	295.000	71.330	4.459201E+07	4.400889E+01	4.874977E-03
26227.10	-240.900	291.498	65.027	4.288581E+07	4.232500E+01	4.743638E-03
26232.10	-235.900	287.427	57.698	4.096061E+07	4.042498E+01	4.593565E-03
26237.10	-230.900	283.355	50.369	3.909743E+07	3.858616E+01	4.446321E-03
26242.10	-225.900	279.283	43.040	3.729505E+07	3.680735E+01	4.301887E-03
26247.10	-220.900	275.212	35.711	3.555228E+07	3.508737E+01	4.160245E-03
26252.10	-215.900	271.140	28.382	3.386792E+07	3.342504E+01	4.021377E-03
26253.50	-214.500	270.000	26.330	3.340661E+07	3.296976E+01	3.982989E-03
26257.10	-210.900	267.050	21.020	3.224026E+07	3.181866E+01	3.888885E-03
26260.70	-207.300	264.100	15.710	3.110193E+07	3.069522E+01	3.795974E-03
26262.10	-205.900	262.923	13.591	3.066677E+07	3.026575E+01	3.759565E-03
26267.10	-200.900	258.718	6.022	2.914698E+07	2.876583E+01	3.631121E-03
26272.10	-195.900	254.513	-1.547	2.768007E+07	2.731811E+01	3.505143E-03
26277.10	-190.900	250.308	-9.116	2.626499E+07	2.592153E+01	3.381621E-03
26282.10	-185.900	246.103	-16.685	2.490069E+07	2.457507E+01	3.260543E-03
26287.10	-180.900	241.898	-24.253	2.358613E+07	2.327770E+01	3.141897E-03
26292.10	-175.900	237.693	-31.822	2.232028E+07	2.202841E+01	3.025673E-03
26297.10	-170.900	233.488	-39.391	2.110211E+07	2.082617E+01	2.911857E-03
26302.10	-165.900	229.283	-46.960	1.993060E+07	1.966998E+01	2.800440E-03
26307.10	-160.900	225.078	-54.529	1.880473E+07	1.855883E+01	2.691408E-03
26312.10	-155.900	220.874	-62.098	1.772350E+07	1.749173E+01	2.584751E-03
26317.10	-150.900	216.669	-69.666	1.668588E+07	1.646769E+01	2.480457E-03

TABLE 5-R356397

URANUS DATE 01/13/72.
NOMINAL URANUS ATMOSPHERE,
MEAN MOLECULAR MASS = 2.680 GRAMS/MOLE
INITIAL PRESSURE =1.013250E+06 DYNES/SQCM AT 26468.00 KM RADIUS
PRINT INTERVAL = 5 KM, GAS CONSTANT = 8.31430000E+07 JOULES/(MOLE.DEG KELVIN)
ONE ATMOSPHERE = 1.01325000E+06 DYNES/CM2, MU= 5.67444957E+06 KM3/SEC2
GREF = 8.09993416E-03 KM/SEC2

ALTITUDE IS ABOVE 26468.0 KM RADIUS

RADIUS	ALTITUDE	TEMPERATURE		PRESSURE		DENSITY
KM	KM	KELVIN	FAHREN	DYNE/CM2	ATMOSPHERES	GM/CM3
26322.10	-145.900	212.464	-77.235	1.569090E+07	1.548572E+01	2.378515E-03
26327.10	-140.900	208.259	-84.804	1.473756E+07	1.454484E+01	2.278912E-03
26332.10	-135.900	204.054	-92.373	1.382486E+07	1.364408E+01	2.181636E-03
26337.10	-130.900	199.849	-99.942	1.295183E+07	1.278246E+01	2.086677E-03
26342.10	-125.900	195.644	-107.511	1.211750E+07	1.195904E+01	1.994023E-03
26347.10	-120.900	191.439	-115.079	1.132089E+07	1.117285E+01	1.903660E-03
26352.10	-115.900	187.234	-122.648	1.056104E+07	1.042294E+01	1.815579E-03
26354.40	-113.600	185.300	-126.130	1.022359E+07	1.008990E+01	1.775824E-03
26357.10	-110.900	182.964	-130.335	9.836986E+06	9.708351E+00	1.729892E-03
26362.10	-105.900	178.638	-138.121	9.147702E+06	9.028080E+00	1.646547E-03
26367.10	-100.900	174.312	-145.908	8.492247E+06	8.381196E+00	1.565419E-03
26372.10	-95.900	169.987	-153.694	7.869692E+06	7.766782E+00	1.486497E-03
26377.10	-90.900	165.661	-161.481	7.279114E+06	7.183927E+00	1.409771E-03
26381.10	-86.900	162.200	-167.710	6.829060E+06	6.739758E+00	1.349963E-03
26382.10	-85.900	161.333	-169.271	6.719569E+06	6.631699E+00	1.335941E-03
26387.10	-80.900	156.995	-177.079	6.189227E+06	6.108292E+00	1.266852E-03
26389.40	-78.600	155.000	-180.670	5.954716E+06	5.876848E+00	1.235642E-03
26392.10	-75.900	152.611	-184.971	5.686955E+06	5.612589E+00	1.198851E-03
26397.10	-70.900	148.186	-192.935	5.212364E+06	5.144204E+00	1.132152E-03
26400.70	-67.300	145.000	-198.670	4.887394E+06	4.823483E+00	1.085283E-03
26402.10	-65.900	143.751	-200.918	4.764730E+06	4.702423E+00	1.067270E-03
26407.10	-60.900	139.290	-208.947	4.343318E+06	4.286521E+00	1.004146E-03
26412.10	-55.900	134.830	-216.976	3.947360E+06	3.895741E+00	9.429103E-04
26417.10	-50.900	130.369	-225.005	3.576068E+06	3.529305E+00	8.835620E-04
26422.10	-45.900	125.909	-233.034	3.228658E+06	3.186437E+00	8.261017E-04
26424.80	-43.200	123.500	-237.370	3.050709E+06	3.010816E+00	7.958584E-04
26427.10	-40.900	121.397	-241.155	2.904315E+06	2.866336E+00	7.708198E-04
26432.10	-35.900	116.825	-249.385	2.602078E+06	2.568051E+00	7.176875E-04
26437.10	-30.900	112.253	-257.614	2.321166E+06	2.290813E+00	6.663396E-04
26442.10	-25.900	107.682	-265.843	2.060838E+06	2.033889E+00	6.167820E-04
26447.10	-20.900	103.110	-274.072	1.820350E+06	1.796545E+00	5.690211E-04
26452.10	-15.900	98.538	-282.301	1.598957E+06	1.578048E+00	5.230639E-04
26457.10	-10.900	93.966	-290.530	1.395912E+06	1.377658E+00	4.789179E-04
26462.10	-5.900	89.395	-298.760	1.210466E+06	1.194638E+00	4.365916E-04
26467.10	-.900	84.823	-306.989	1.041867E+06	1.028243E+00	3.960940E-04
26468.00	0.	84.000	-308.470	1.013250E+06	1.000000E+00	3.889994E-04
26470.30	2.300	81.900	-312.250	9.424638E+05	9.301394E-01	3.710553E-04
26472.10	4.100	80.199	-315.312	8.893812E+05	8.777510E-01	3.573229E-04
26477.10	9.100	75.473	-323.819	7.522641E+05	7.424269E-01	3.204526E-04
26477.60	9.600	75.000	-324.670	7.393676E+05	7.296991E-01	3.168690E-04
26482.10	14.100	71.218	-331.477	6.319937E+05	6.237292E-01	2.737923E-04
26487.10	19.100	67.017	-339.040	5.298433E+05	5.229147E-01	2.323411E-04
26489.50	21.500	65.000	-342.670	4.864899E+05	4.801282E-01	2.145877E-04
26492.10	24.100	62.942	-346.374	4.430145E+05	4.372213E-01	1.991421E-04
26497.10	29.100	58.986	-353.496	3.681521E+05	3.633379E-01	1.717982E-04
26502.10	34.100	55.029	-360.618	3.037691E+05	2.997968E-01	1.473713E-04
26503.40	35.400	54.000	-362.470	2.886031E+05	2.848291E-01	1.414712E-04

TABLE 5-R356397

URANUS DATE 01/13/72.

NOMINAL URANUS ATMOSPHERE,
MEAN MOLECULAR MASS = 2.680 GRAMS/MOLE
INITIAL PRESSURE =1.013250E+06 DYNES/SQCM AT 26468.00 KM RADIUS
PRINT INTERVAL = 5 KM, GAS CONSTANT = 8.31430000E+07 JOULES/(MOLE.DEG KELVIN)
ONE ATMOSPHERE = 1.01325000E+06 DYNES/CM2, MU= 5.67444957E+06 KM3/SEC2
GREF = 8.09993416E-03 KM/SEC2

ALTITUDE IS ABOVE 26468.0 KM RADIUS

RADIUS	ALTITUDE	TEMPERATURE		PRESSURE		DENSITY
KM	KM	KELVIN	FAHREN	DYNE/CM2	ATMOSPHERES	GM/CM3
26507.10	39.100	54.296	-361.937	2.493441E+05	2.460835E-01	1.217624E-04
26512.10	44.100	54.696	-361.217	2.048311E+05	2.021526E-01	9.951456E-05
26517.10	49.100	55.096	-360.497	1.684457E+05	1.662430E-01	8.142135E-05
26522.10	54.100	55.496	-359.777	1.386712E+05	1.368578E-01	6.669043E-05
26527.10	59.100	55.896	-359.057	1.142800E+05	1.127856E-01	5.468365E-05
26530.90	62.900	56.200	-358.510	9.872365E+04	9.743266E-02	4.705996E-05
26532.10	64.100	56.302	-358.327	9.427877E+04	9.304591E-02	4.485678E-05
26537.10	69.100	56.725	-357.565	7.788826E+04	7.686974E-02	3.677071E-05
26542.10	74.100	57.148	-356.804	6.444696E+04	6.360420E-02	3.019078E-05
26547.10	79.100	57.571	-356.042	5.340659E+04	5.270820E-02	2.482759E-05
26552.10	84.100	57.994	-355.280	4.432402E+04	4.374441E-02	2.044899E-05
26557.10	89.100	58.418	-354.518	3.684050E+04	3.635874E-02	1.686850E-05
26562.10	94.100	58.841	-353.757	3.066509E+04	3.026409E-02	1.393599E-05
26562.80	94.800	58.900	-353.650	2.989088E+04	2.950001E-02	1.356995E-05
26567.10	99.100	59.256	-353.009	2.555957E+04	2.522533E-02	1.154055E-05
26572.10	104.100	59.670	-352.264	2.133003E+04	2.105110E-02	9.570380E-06
26577.10	109.100	60.084	-351.519	1.782176E+04	1.758871E-02	7.946391E-06
26582.10	114.100	60.498	-350.774	1.490817E+04	1.471322E-02	6.606055E-06
26587.10	119.100	60.912	-350.029	1.248550E+04	1.232223E-02	5.498438E-06
26592.10	124.100	61.325	-349.284	1.046863E+04	1.033174E-02	4.581999E-06
26593.00	125.000	61.400	-349.150	1.014308E+04	1.001044E-02	4.434620E-06
26597.10	129.100	61.732	-348.553	8.787887E+03	8.672970E-03	3.821124E-06
26602.10	134.100	62.136	-347.825	7.386038E+03	7.289452E-03	3.190313E-06
26607.10	139.100	62.540	-347.097	6.215338E+03	6.134062E-03	2.666987E-06
26612.10	144.100	62.945	-346.369	5.236454E+03	5.167978E-03	2.232268E-06
26617.10	149.100	63.349	-345.641	4.416948E+03	4.359189E-03	1.870695E-06
26622.10	154.100	63.754	-344.913	3.730038E+03	3.681261E-03	1.569581E-06
26627.10	159.100	64.158	-344.185	3.153577E+03	3.112338E-03	1.318506E-06
26632.10	164.100	64.562	-343.458	2.669234E+03	2.634329E-03	1.108896E-06
26637.10	169.100	64.967	-342.730	2.261812E+03	2.232234E-03	9.336931E-07
26642.10	174.100	65.371	-342.002	1.918599E+03	1.893608E-03	7.870735E-07
26647.10	179.100	65.776	-341.274	1.629414E+03	1.608107E-03	6.642293E-07
26652.10	184.100	66.180	-340.546	1.385240E+03	1.367125E-03	5.611853E-07
26657.10	189.100	66.585	-339.818	1.178911E+03	1.163495E-03	4.746506E-07
26661.00	193.000	65.900	-339.250	1.040314E+03	1.026710E-03	4.168425E-07
26662.10	194.100	66.991	-339.087	1.004371E+03	9.912372E-04	4.018946E-07
26667.10	199.100	67.403	-338.345	8.565653E+02	8.453642E-04	3.406500E-07
26672.10	204.100	67.815	-337.603	7.312652E+02	7.217026E-04	2.890474E-07
26677.10	209.100	68.227	-336.861	6.249310E+02	6.167590E-04	2.455209E-07
26682.10	214.100	68.639	-336.119	5.345972E+02	5.276064E-04	2.087668E-07
26687.10	219.100	69.051	-335.377	4.577764E+02	4.517901E-04	1.776978E-07
26692.10	224.100	69.464	-334.635	3.923801E+02	3.872491E-04	1.514068E-07
26697.10	229.100	69.876	-333.894	3.366531E+02	3.322507E-04	1.291355E-07
26702.10	234.100	70.288	-333.152	2.891179E+02	2.853372E-04	1.102499E-07
26707.10	239.100	70.700	-332.410	2.485303E+02	2.452804E-04	9.421883E-08
26712.10	244.100	71.112	-331.668	2.138410E+02	2.110447E-04	8.059707E-08

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URANUS DATE 01/13/72.

NOMINAL URANUS ATMOSPHERE,
MEAN MOLECULAR MASS = 2.680 GRAMS/MOLE
INITIAL PRESSURE =1.013250E+06 DYNES/SQCM AT 26468.00 KM RADIUS
PRINT INTERVAL = 5 KM, GAS CONSTANT = 8.31430000E+07 JOULES/(MOLE.DEG KELVIN)
ONE ATMOSPHERE = 1.01325000E+06 DYNES/CM2, MU= 5.67444957E+06 KM3/SEC2
GREF = 8.09993416E-03 KM/SEC2

ALTITUDE IS ABOVE 26468.0 KM RADIUS

RADIUS	ALTITUDE	TEMPERATURE		PRESSURE		DENSITY
KM	KM	KELVIN	FAHREN	DYNE/CM2	ATMOSPHERES	GM/CM3
26717.10	249.100	71.524	-330.926	1.841641E+02	1.817559E-04	6.901092E-08
26722.10	254.100	71.937	-330.184	1.587512E+02	1.566752E-04	5.914646E-08
26727.10	259.100	72.349	-329.442	1.369689E+02	1.351778E-04	5.073962E-08
26732.10	264.100	72.761	-328.700	1.182812E+02	1.167345E-04	4.356809E-08
26735.00	267.000	73.000	-328.270	1.086782E+02	1.072571E-04	3.989952E-08
26737.10	269.100	73.175	-327.954	1.022338E+02	1.008969E-04	3.744306E-08
26742.10	274.100	73.593	-327.202	8.844191E+01	8.728537E-05	3.220692E-08
26747.10	279.100	74.011	-326.450	7.657787E+01	7.557648E-05	2.772828E-08
26752.10	284.100	74.429	-325.699	6.636295E+01	6.549514E-05	2.389394E-08
26757.10	289.100	74.846	-324.947	5.756004E+01	5.680734E-05	2.060817E-08
26762.10	294.100	75.264	-324.195	4.996723E+01	4.931382E-05	1.778990E-08
26767.10	299.100	75.682	-323.443	4.341244E+01	4.284474E-05	1.537042E-08
26772.10	304.100	76.099	-322.691	3.774884E+01	3.725521E-05	1.329144E-08
26777.10	309.100	76.517	-321.939	3.285109E+01	3.242150E-05	1.150346E-08
26782.10	314.100	76.935	-321.187	2.861203E+01	2.823787E-05	9.964381E-09
26787.10	319.100	77.353	-320.435	2.493999E+01	2.461386E-05	8.638416E-09
26792.10	324.100	77.770	-319.683	2.175651E+01	2.147200E-05	7.495072E-09
26797.10	329.100	78.188	-318.931	1.899430E+01	1.874592E-05	6.508359E-09
26802.10	334.100	78.606	-318.180	1.659568E+01	1.637867E-05	5.656104E-09
26807.10	339.100	79.024	-317.428	1.451113E+01	1.432137E-05	4.919373E-09
26812.10	344.100	79.441	-316.676	1.269807E+01	1.253202E-05	4.281983E-09
26814.00	346.000	79.600	-316.390	1.207250E+01	1.191463E-05	4.062874E-09
26817.10	349.100	79.848	-315.944	1.111982E+01	1.097441E-05	3.730763E-09
26822.10	354.100	80.248	-315.224	9.744629E+00	9.617201E-06	3.253261E-09
26827.10	359.100	80.648	-314.504	8.545474E+00	8.433727E-06	2.838925E-09
26832.10	364.100	81.048	-313.784	7.499067E+00	7.401004E-06	2.479132E-09
26837.10	369.100	81.448	-313.064	6.585301E+00	6.499187E-06	2.166472E-09
26842.10	374.100	81.848	-312.344	5.786800E+00	5.711127E-06	1.894572E-09
26847.10	379.100	82.248	-311.624	5.088536E+00	5.021994E-06	1.657948E-09
26852.10	384.100	82.648	-310.904	4.477504E+00	4.418952E-06	1.451876E-09
26857.10	389.100	83.048	-310.184	3.942440E+00	3.890885E-06	1.272284E-09
26862.10	394.100	83.448	-309.464	3.473581E+00	3.428158E-06	1.115659E-09
26867.10	399.100	83.848	-308.744	3.062459E+00	3.022412E-06	9.789703E-10
26872.10	404.100	84.248	-308.024	2.701725E+00	2.666395E-06	8.595973E-10
26877.10	409.100	84.648	-307.304	2.384993E+00	2.353806E-06	7.552756E-10
26882.10	414.100	85.048	-306.584	2.106716E+00	2.079167E-06	6.640458E-10
26887.10	419.100	85.448	-305.864	1.862066E+00	1.837716E-06	5.842116E-10
26892.10	424.100	85.848	-305.144	1.646841E+00	1.625305E-06	5.143033E-10
26897.10	429.100	86.248	-304.424	1.457382E+00	1.438324E-06	4.530466E-10
26902.10	434.100	86.648	-303.704	1.290500E+00	1.273624E-06	3.993359E-10
26904.00	436.000	86.800	-303.430	1.232413E+00	1.216297E-06	3.807005E-10
26907.10	439.100	87.055	-302.971	1.143416E+00	1.128464E-06	3.521784E-10
26912.10	444.100	87.467	-302.230	1.013716E+00	1.000460E-06	3.107680E-10
26917.10	449.100	87.878	-301.490	8.992737E-01	8.875141E-07	2.743993E-10
26922.10	454.100	88.289	-300.749	7.982310E-01	7.877927E-07	2.424377E-10
26927.10	459.100	88.701	-300.008	7.089637E-01	6.996928E-07	2.143313E-10

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URANUS DATE 01/13/72.
NOMINAL URANUS ATMOSPHERE,
MEAN MOLECULAR MASS = 2.680 GRAMS/MOLE
INITIAL PRESSURE =1.013250E+06 DYNES/SQCM AT 26468.00 KM RADIUS
PRINT INTERVAL = 5 KM, GAS CONSTANT = 8.31430000E+07 JOULES/(MOLE.DEG KELVIN)
ONE ATMOSPHERE = 1.01325000E+06 DYNES/CM2, MU= 5.67444957E+06 KM3/SEC2
GREF = 8.09993416E-03 KM/SEC2

ALTITUDE IS ABOVE 26468.0 KM RADIUS

RADIUS	ALTITUDE	TEMPERATURE		PRESSURE		DENSITY
KM	KM	KELVIN	FAHREN	DYNE/CM2	ATMOSPHERES	GM/CM3
26932.10	464.100	89.112	-299.268	6.300511E-01	6.218121E-07	1.895992E-10
26937.10	469.100	89.524	-298.527	5.602495E-01	5.529233E-07	1.678226E-10
26942.10	474.100	89.935	-297.786	4.984697E-01	4.919514E-07	1.486364E-10
26947.10	479.100	90.347	-297.046	4.437573E-01	4.379544E-07	1.317220E-10
26952.10	484.100	90.758	-296.305	3.952749E-01	3.901060E-07	1.168013E-10
26957.10	489.100	91.170	-295.565	3.522880E-01	3.476812E-07	1.036311E-10
26962.10	494.100	91.581	-294.824	3.141514E-01	3.100433E-07	9.199929E-11
26967.10	499.100	91.993	-294.083	2.802984E-01	2.766330E-07	8.171990E-11
26972.10	504.100	92.404	-293.343	2.502307E-01	2.469585E-07	7.263034E-11
26977.10	509.100	92.816	-292.602	2.235099E-01	2.205871E-07	6.458818E-11
26982.10	514.100	93.227	-291.861	1.997501E-01	1.971380E-07	5.746859E-11
26987.10	519.100	93.638	-291.121	1.786115E-01	1.762758E-07	5.116212E-11
26992.10	524.100	94.050	-290.380	1.597944E-01	1.577048E-07	4.557270E-11
26997.10	529.100	94.461	-289.640	1.430348E-01	1.411644E-07	4.061601E-11
27000.00	532.000	94.700	-289.210	1.341640E-01	1.324096E-07	3.800146E-11

TABLE 5-R356397

URANUS DATE 01/13/72.
NOMINAL URANUS ATMOSPHERE,
MEAN MOLECULAR MASS = 2.680 GRAMS/MOLE
INITIAL PRESSURE =1.013250E+06 DYNES/SQCM AT 26468.00 KM RADIUS
PRINT INTERVAL = 5 KM, GAS CONSTANT = 8.31430000E+07 JOULES/(MOLE.DEG KELVIN)
ONE ATMOSPHERE = 1.01325000E+06 DYNES/CM2, MU= 5.67444957E+06 KM3/SEC2
GREF = 8.09993416E-03 KM/SEC2

TEMPERATURE PROFILE INPUTS

BASE ALTITUDE KM	KFT	KINETIC TEMPERATURE KELVIN	RANKINE	MOLEC SCALE TEMP KELVIN	RANKINE	MOLEC WT G/GMOLE
-355.900	*167.651	382.300	688.140	382.446	688.402	2.679
-295.500	-969.488	306.600	551.880	306.353	551.435	2.682
-245.200	-804.462	295.000	531.000	294.845	530.721	2.681
-214.500	-703.740	270.000	486.000	270.354	486.637	2.676
-207.300	-680.118	264.100	475.380	264.103	475.385	2.680
-113.600	-372.703	185.300	333.540	185.572	334.030	2.676
-86.900	-285.105	162.200	291.960	163.060	293.509	2.665
-78.600	-257.874	155.000	279.000	155.338	279.608	2.674
-67.300	-220.801	145.000	261.000	145.159	261.286	2.677
-43.200	-141.732	123.500	222.300	123.559	222.406	2.679
0.	0.	84.000	151.200	83.961	151.130	2.681
2.300	7.546	81.900	147.420	81.872	147.370	2.681
9.600	31.496	75.000	135.000	75.212	135.382	2.672
21.500	70.538	65.000	117.000	73.077	131.538	2.384
35.400	116.142	54.000	97.200	65.757	118.363	2.201
62.900	206.365	56.200	101.160	67.621	121.717	2.227
94.800	311.024	58.900	106.020	71.002	127.803	2.223
125.000	410.105	61.400	110.520	73.726	132.707	2.232
193.000	633.202	66.900	120.420	80.445	144.802	2.229
267.000	875.984	73.000	131.400	87.798	158.036	2.228
346.000	1135.171	79.600	143.280	95.780	172.403	2.227
436.000	1430.446	86.800	156.240	104.348	187.826	2.229
532.000	1745.407	94.700	170.460	113.801	204.841	2.230

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NEPTUN DATE 01/13/72.
NOMINAL NEPTUNE ATMOSPHERE,
MEAN MOLECULAR MASS = 2.680 GRAMS/MOLE
INITIAL PRESSURE =1.013250E+06 DYNES/SQCM AT 24857.00 KM RADIUS
PRINT INTERVAL = 5 KM, GAS CONSTANT = 8.31430000E+07 JOULES/(MOLE.DEG KELVIN)
ONE ATMOSPHERE = 1.01325000E+06 DYNES/CM2, MU= 6.79657494E+06 KM3/SEC2
GREF = 1.10000000E-02 KM/SEC2

ALTITUDE IS ABOVE 24857.0 KM RADIUS

RADIUS	ALTITUDE	TEMPERATURE		PRESSURE		DENSITY
KM	KM	KELVIN	FAHREN	DYNE/CM2	ATMOSPHERES	GM/CM3
24675.00	-182.000	270.000	26.330	9.584474E+07	9.459140E+01	1.148394E-02
24680.00	-177.000	264.315	16.097	8.958245E+07	8.841100E+01	1.096256E-02
24685.00	-172.000	258.630	5.864	8.360975E+07	8.251641E+01	1.045467E-02
24690.00	-167.000	252.945	-4.369	7.791893E+07	7.690000E+01	9.960170E-03
24695.00	-162.000	247.260	-14.602	7.250230E+07	7.155421E+01	9.478985E-03
24700.00	-157.000	241.575	-24.834	6.735227E+07	6.647152E+01	9.011023E-03
24705.00	-152.000	235.890	-35.067	6.246126E+07	6.164447E+01	8.556196E-03
24710.00	-147.000	230.205	-45.300	5.782179E+07	5.706567E+01	8.114417E-03
24715.00	-142.000	224.521	-55.533	5.342642E+07	5.272777E+01	7.685596E-03
24720.00	-137.000	218.836	-65.766	4.926776E+07	4.862350E+01	7.269646E-03
24725.00	-132.000	213.151	-75.999	4.533850E+07	4.474562E+01	6.866475E-03
24730.00	-127.000	207.466	-86.232	4.163136E+07	4.108696E+01	6.475994E-03
24735.00	-122.000	201.781	-96.465	3.813916E+07	3.764042E+01	6.098112E-03
24740.00	-117.000	196.096	-106.697	3.485473E+07	3.439895E+01	5.732737E-03
24745.00	-112.000	190.411	-116.930	3.177101E+07	3.135555E+01	5.379778E-03
24748.00	-109.000	187.000	-123.070	3.001418E+07	2.962170E+01	5.173923E-03
24750.00	-107.000	184.597	-127.395	2.888045E+07	2.850279E+01	5.043681E-03
24755.00	-102.000	178.590	-138.209	2.617171E+07	2.582947E+01	4.725326E-03
24760.00	-97.000	172.582	-149.022	2.363771E+07	2.332860E+01	4.417318E-03
24761.40	-95.600	170.900	-152.050	2.295870E+07	2.265847E+01	4.332929E-03
24765.00	-92.000	166.652	-159.696	2.127170E+07	2.099354E+01	4.123846E-03
24766.40	-90.600	165.000	-162.670	2.063816E+07	2.036828E+01	4.043838E-03
24770.00	-87.000	160.714	-170.384	1.906908E+07	1.881971E+01	3.825459E-03
24774.80	-82.200	155.000	-180.670	1.711045E+07	1.688670E+01	3.545217E-03
24775.00	-82.000	154.760	-181.102	1.703205E+07	1.680933E+01	3.534596E-03
24780.00	-77.000	148.755	-191.911	1.514809E+07	1.495000E+01	3.274020E-03
24785.00	-72.000	142.750	-202.719	1.340642E+07	1.323111E+01	3.022979E-03
24790.00	-67.000	136.746	-213.528	1.180166E+07	1.164733E+01	2.781495E-03
24795.00	-62.000	130.741	-224.336	1.032841E+07	1.019335E+01	2.549594E-03
24796.20	-60.800	129.300	-226.930	9.993800E+06	9.863114E+00	2.495366E-03
24800.00	-57.000	124.606	-235.379	8.981310E+06	8.863864E+00	2.327079E-03
24805.00	-52.000	118.429	-246.497	7.755030E+06	7.653620E+00	2.114195E-03
24810.00	-47.000	112.253	-257.615	6.644110E+06	6.557227E+00	1.911052E-03
24815.00	-42.000	106.076	-268.732	5.643072E+06	5.569279E+00	1.717686E-03
24820.00	-37.000	99.900	-279.850	4.746421E+06	4.684353E+00	1.534135E-03
24825.00	-32.000	93.724	-290.968	3.948648E+06	3.897013E+00	1.360443E-03
24828.50	-28.500	89.400	-298.750	3.446081E+06	3.401018E+00	1.244751E-03
24830.00	-27.000	87.483	-302.200	3.247699E+06	3.205229E+00	1.155835E-03
24832.10	-24.900	84.800	-307.030	2.993371E+06	2.954228E+00	1.043823E-03
24835.00	-22.000	81.417	-313.120	2.675280E+06	2.640296E+00	9.480002E-04
24840.00	-17.000	75.583	-323.620	2.194770E+06	2.166069E+00	8.000548E-04
24840.50	-16.500	75.000	-324.670	2.151085E+06	2.122955E+00	7.863879E-04
24845.00	-12.000	70.055	-333.571	1.784360E+06	1.761026E+00	6.945711E-04
24849.60	-7.400	65.000	-342.670	1.455159E+06	1.436130E+00	6.065882E-04
24850.00	-7.000	64.568	-343.448	1.428610E+06	1.409929E+00	5.994706E-04
24855.00	-2.000	59.162	-353.178	1.122655E+06	1.107974E+00	5.136666E-04
24857.00	0.	57.000	-357.070	1.013250E+06	1.000000E+00	4.809994E-04

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NEPTUN DATE 01/13/72.

NOMINAL NEPTUNE ATMOSPHERE,
MEAN MOLECULAR MASS = 2.680 GRAMS/MOLE
INITIAL PRESSURE =1.013250E+06 DYNES/SQCM AT 24857.00 KM RADIUS
PRINT INTERVAL = 5 KM, GAS CONSTANT = 8.31430000E+07 JOULES/(MOLE.DEG KELVIN)
ONE ATMOSPHERE = 1.01325000E+06 DYNES/CM2, MU= 6.79657494E+06 KM3/SEC2
GREF = 1.10000000E-02 KM/SEC2

ALTITUDE IS ABOVE 24857.0 KM RADIUS

RADIUS	ALTITUDE	TEMPERATURE		PRESSURE		DENSITY
KM	KM	KELVIN	FAHREN	DYNE/CM2	ATMOSPHERES	GM/CM3
24860.00	3.000	53.691	-363.026	8.623075E+05	8.510314E-01	4.342512E-04
24865.00	8.000	48.176	-372.952	6.439979E+05	6.355765E-01	3.609099E-04
24870.00	13.000	42.662	-382.879	4.644805E+05	4.584056E-01	2.934158E-04
24870.60	13.600	42.000	-384.070	4.453900E+05	4.395658E-01	2.857175E-04
24875.00	18.000	42.652	-382.897	3.272356E+05	3.229564E-01	2.074648E-04
24876.00	19.000	42.800	-382.630	3.052519E+05	3.012602E-01	1.930140E-04
24880.00	23.000	43.438	-381.482	2.316992E+05	2.286693E-01	1.443539E-04
24885.00	28.000	44.236	-380.046	1.651048E+05	1.629458E-01	1.010095E-04
24890.00	33.000	45.033	-378.610	1.183812E+05	1.168332E-01	7.114180E-05
24892.30	35.300	45.400	-377.950	1.017887E+05	1.004577E-01	6.067616E-05
24895.00	38.000	45.814	-377.204	8.538791E+04	8.427132E-02	5.042507E-05
24900.00	43.000	46.581	-375.823	6.194369E+04	6.113367E-02	3.595941E-05
24905.00	48.000	47.349	-374.442	4.518549E+04	4.459451E-02	2.579319E-05
24910.00	53.000	48.116	-373.061	3.313773E+04	3.270439E-02	1.860545E-05
24911.20	54.200	48.300	-372.730	3.078487E+04	3.038231E-02	1.721659E-05
24915.00	58.000	48.878	-371.689	2.442655E+04	2.410713E-02	1.350114E-05
24920.00	63.000	49.639	-370.320	1.809159E+04	1.785501E-02	9.848334E-06
24925.00	68.000	50.400	-368.950	1.346174E+04	1.328571E-02	7.218790E-06
24929.60	72.600	51.100	-367.690	1.029722E+04	1.016256E-02	5.447123E-06
24930.00	73.000	51.161	-367.580	1.006182E+04	9.930240E-03	5.316276E-06
24935.00	78.000	51.928	-366.200	7.553637E+03	7.454860E-03	3.932664E-06
24940.00	83.000	52.694	-364.820	5.694997E+03	5.620525E-03	2.922246E-06
24945.00	88.000	53.461	-363.440	4.311570E+03	4.255189E-03	2.180929E-06
24950.00	93.000	54.227	-362.061	3.277411E+03	3.234553E-03	1.634585E-06
24955.00	98.000	54.994	-360.681	2.501100E+03	2.468393E-03	1.230166E-06
24960.00	103.000	55.760	-359.301	1.915971E+03	1.890916E-03	9.295236E-07
24965.00	108.000	56.527	-357.922	1.473194E+03	1.453929E-03	7.051003E-07
24970.00	113.000	57.293	-356.542	1.136843E+03	1.121977E-03	5.368955E-07
24972.00	115.000	57.600	-355.990	1.025905E+03	1.012489E-03	4.819445E-07
24975.00	118.000	58.072	-355.140	8.803955E+02	8.688828E-04	4.102370E-07
24980.00	123.000	58.860	-353.723	6.842021E+02	6.752550E-04	3.145693E-07
24985.00	128.000	59.647	-352.306	5.335603E+02	5.265830E-04	2.420848E-07
24990.00	133.000	60.434	-350.889	4.174802E+02	4.120210E-04	1.869593E-07
24995.00	138.000	61.221	-349.472	3.277210E+02	3.234355E-04	1.448824E-07
25000.00	143.000	62.009	-348.055	2.580789E+02	2.547041E-04	1.126511E-07
25005.00	148.000	62.796	-346.638	2.038665E+02	2.012006E-04	8.787588E-08
25010.00	153.000	63.583	-345.221	1.615291E+02	1.594159E-04	6.876755E-08
25015.00	158.000	64.370	-343.804	1.283617E+02	1.266831E-04	5.398125E-08
25019.00	162.000	65.000	-342.670	1.070245E+02	1.056250E-04	4.457357E-08
25020.00	163.000	65.155	-342.392	1.022983E+02	1.009606E-04	4.250227E-08
25025.00	168.000	65.928	-340.999	8.175658E+01	8.068747E-05	3.356234E-08
25030.00	173.000	66.702	-339.607	6.551945E+01	6.466267E-05	2.657954E-08
25035.00	178.000	67.475	-338.214	5.264814E+01	5.195968E-05	2.110904E-08
25040.00	183.000	68.249	-336.822	4.241643E+01	4.186176E-05	1.681074E-08
25045.00	188.000	69.023	-335.429	3.426079E+01	3.381277E-05	1.342378E-08
25050.00	193.000	69.796	-334.037	2.774263E+01	2.737984E-05	1.074747E-08

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ONE ATMOSPHERE = 1.01325000E+06 DYNES/CM2, MU= 6.79657494E+06 KM3/SEC2
GREF = 1.10000000E-02 KM/SEC2

ALTITUDE IS ABOVE 24857.0 KM RADIUS

RADIUS	ALTITUDE	TEMPERATURE		PRESSURE		DENSITY
KM	KM	KELVIN	FAHREN	DYNE/CM2	ATMOSPHERES	GM/CM3
25055.00	198.000	70.570	-332.644	2.251958E+01	2.222510E-05	8.626910E-09
25060.00	203.000	71.343	-331.252	1.832366E+01	1.808404E-05	6.942201E-09
25065.00	208.000	72.117	-329.859	1.494446E+01	1.474903E-05	5.600258E-09
25070.00	213.000	72.891	-328.467	1.221638E+01	1.205663E-05	4.528607E-09
25072.00	215.000	73.200	-327.910	1.127719E+01	1.112972E-05	4.162508E-09
25075.00	218.000	73.657	-327.087	1.000857E+01	9.877687E-06	3.671407E-09
25080.00	223.000	74.420	-325.715	8.217233E+00	8.109778E-06	2.983553E-09
25085.00	228.000	75.182	-324.342	6.760554E+00	6.672148E-06	2.429870E-09
25090.00	233.000	75.944	-322.970	5.573445E+00	5.500562E-06	1.983177E-09
25095.00	238.000	76.707	-321.598	4.603969E+00	4.543764E-06	1.621399E-09
25100.00	243.000	77.469	-320.226	3.810580E+00	3.760750E-06	1.329328E-09
25105.00	248.000	78.231	-318.854	3.159972E+00	3.118650E-06	1.091664E-09
25110.00	253.000	78.993	-317.482	2.625384E+00	2.591052E-06	8.982641E-10
25115.00	258.000	79.756	-316.110	2.185264E+00	2.156688E-06	7.405612E-10
25120.00	263.000	80.518	-314.738	1.822224E+00	1.798395E-06	6.117073E-10
25125.00	268.000	81.280	-313.365	1.522198E+00	1.502293E-06	5.062170E-10
25130.00	273.000	82.043	-311.993	1.273790E+00	1.257133E-06	4.196865E-10
25133.00	276.000	82.500	-311.170	1.145596E+00	1.130616E-06	3.753649E-10
25135.00	278.000	82.813	-310.606	1.057748E+00	1.043786E-06	3.485523E-10
25140.00	283.000	83.597	-309.195	8.965600E-01	8.848359E-07	2.899661E-10
25145.00	288.000	84.381	-307.785	7.540803E-01	7.442194E-07	2.416526E-10
25150.00	293.000	85.164	-306.374	6.352876E-01	6.269801E-07	2.017375E-10
25155.00	298.000	85.948	-304.964	5.350741E-01	5.280640E-07	1.687015E-10
25160.00	303.000	86.731	-303.554	4.530731E-01	4.471484E-07	1.413109E-10
25165.00	308.000	87.515	-302.143	3.835205E-01	3.785053E-07	1.185615E-10
25170.00	313.000	88.299	-300.733	3.251425E-01	3.208907E-07	9.963464E-11
25175.00	318.000	89.082	-299.322	2.760656E-01	2.724555E-07	8.386170E-11
25180.00	323.000	89.866	-297.912	2.347430E-01	2.316734E-07	7.069548E-11
25185.00	328.000	90.649	-296.501	1.998960E-01	1.972820E-07	5.968741E-11
25190.00	333.000	91.433	-295.091	1.704652E-01	1.682361E-07	5.046911E-11
25195.00	338.000	92.216	-293.680	1.455718E-01	1.436682E-07	4.273753E-11
25200.00	343.000	93.000	-292.270	1.244853E-01	1.228575E-07	3.624293E-11

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ONE ATMOSPHERE = 1.013[illegible]E+06 DYNES/CM2, MU= 6.79657494E+06 KM3/SEC2
GREF = 1.10000000E-02 KM/SE[illegible]

TEMPERATURE PROFILE INPUTS

BASE ALTITUDE KM	KFT	KINETIC TEMPERATURE KELVIN	RANKINE	MOLEC SCALE TEMP KELVIN	RANKINE	MOLEC WT G/GMOLE
-182.000	-597.113	270.000	486.000	269.021	484.238	2.690
-109.000	-357.612	187.000	336.600	186.989	336.580	2.680
-95.600	-313.648	170.900	307.620	170.795	307.431	2.682
-90.600	-297.244	165.000	297.000	164.508	296.114	2.688
-82.200	-269.685	155.000	279.000	155.571	280.027	2.670
-60.800	-199.475	129.300	232.740	129.094	232.369	2.684
-28.500	-93.504	89.400	160.920	89.239	160.629	2.685
-24.900	-81.693	84.800	152.640	92.436	166.385	2.459
-16.500	-54.134	75.000	135.000	88.172	158.709	2.280
-7.400	-24.278	65.000	117.000	77.326	139.187	2.253
0.	0.	57.000	102.600	67.902	122.223	2.250
13.600	44.619	42.000	75.600	50.247	90.445	2.240
19.000	62.335	42.800	77.040	50.978	91.760	2.250
35.300	115.814	45.400	81.720	54.074	97.334	2.250
54.200	177.822	48.300	86.940	57.637	103.746	2.246
72.600	238.189	51.100	91.980	60.934	109.682	2.247
115.000	377.297	57.600	103.680	68.615	123.507	2.250
162.000	531.496	65.000	117.000	77.395	139.312	2.251
215.000	705.381	73.200	131.760	87.328	157.191	2.246
276.000	905.512	82.500	148.500	98.376	177.076	2.248
343.000	1125.328	93.000	167.400	110.714	199.286	2.251

H. REFERENCES

1. NASA Space Vehicle design criteria document for the planet Jupiter (1970), NASA SP-8069, dated August 1971 (See SOW (b(6) (B))

2. NASA Space Vehicle design criteria document for the planet Saturn (1970) (See SOW (C(4) (B))

3. JPL Section Document 131-17 Preliminary Model Atmospheres for the Planets Uranus and Neptune, dated 4 November 1971

4. Constants and Related Information for Astrodynamic Calculations, 1968, by Melbourne, Mulholland, Sjogren, and Sturms, (JPL) NASA technical report 32-1306, dated July 15, 1968

5. Memo from Ken Ledbetter, describing telecon with D. Wiksten and F. Palluconi of JPL, dated 14 January 1972

APPENDIX F

ATTITUDE CONTROL SUBSYSTEM ANALYSIS

E. A. Berkery

June 9, 1972

ATTITUDE CONTROL SUBSYSTEM ANALYSIS

1. Separation

Separation with Initial Spin - The location of the significant vectors is determined by assuming the probe's initial position is correct and the momentum vector is composed of the nominal spin rate along the k (spin) axis and a transverse rate equal to the tipoff rate.

$$\overline{P} = I_s \overline{W}_s + I_t \overline{W}_T$$

$$\tan^{-1} \theta_1 \approx \theta_1 = \frac{W_T I_t}{W_s I_s} = \frac{W_t}{W_s (1 + \lambda)}$$

W_s = spin rate

$\overline{P}$ = momentum vector

P_s = spin momentum

I_s = spin moment of inertia

T_t = transverse moment of inertia

$\lambda = I_s/I_t - 1$

W_t = tip off rate

The motion then consists of nutation around the momentum vector with half cone angle θ_1.

Separation without Spin - There are two types of errors associated with this mode of operation: the initial drift error and the error developed during spinup caused by the combined tipoff and spinup rates.

The drift error is

$$\theta_2 = W_T t_D$$

The error developed during spinup may be analyzed as follows:

$$\dot{\overline{P}} = m \hat{k}$$

m = torque

$$\dot{\hat{k}} = \frac{\overline{P}}{I_t} \times \hat{k}$$

$$\ddot{\overline{P}} = \frac{\overline{P} \times \dot{\overline{P}}}{I_t}$$

$$\overline{P} = \hat{x}p_x + \hat{y}p_y + \hat{z}p_z$$

Assume

$$\dot{p}_z = m \qquad p_z = mt$$

Then

$$\ddot{p}_x = \frac{m}{I_t}\left(p_y - t\dot{p}_y\right)$$

$$\ddot{p}_y = \frac{m}{I_t}\left(t\dot{p}_x - p_x\right)$$

$$\dddot{p}_x = \left(\frac{m}{I_t}\right)^2\left(tp_x - t^2\dot{p}_x\right)$$

$$\dddot{p}_y = \left(\frac{m}{I_t}\right)^2\left(tp_y - t^2\dot{p}_y\right)$$

Assuming

$$p_x = \sum_{n=o}^{\infty} a_n t^n \qquad p_y = \sum_{n=o}^{\infty} b_n t^h$$

and

$$p_x(0) = W_T I_T,\ \dot{p}_x(0) = 0,\ \ddot{p}_x(0) = 0,\ \dddot{p}_x(0) = 0$$

$$p_y(0) = 0,\ \dot{p}_y(0) = 0,\ \ddot{p}_y(0) = -\frac{m}{I_t}p_x(0),\ \dddot{p}_y(0) = 0$$

The solutions

$$p_x = p_x(0)\left[1 + \sum_{n=1}^{\infty} (-1)^{n+1} \left(\frac{P_s^2}{mI_t}\right)^{2N} \frac{(4N-2)!}{(4N)!\ (2N-1)!\ 2^{2N-1}}\right]$$

$$p_y = p_x(0) \sum_{o}^{\infty} \frac{(-1)^{n+1}\ 4N!}{(4N+2)!\ (2N)!\ 2^{2N}} \left(\frac{P_s^2}{mI_t}\right)^{2N+1}$$

This solution is valid for small displacements of the momentum vector $\left(\text{i.e., } p_x, p_y << p_s\right)$. Although it is absolutely convergent, if the value of P_s^2/mI_t is much greater than unity, many terms must be evaluated. For the purpose of simplification, it is sufficient to evaluate the series for a point in time at which the spin momentum becomes considerably greater than the tipoff momentum.

$m = 3$ ft-lb $t = 2$ seconds $I_s = 9$ slug-ft^2 $W_t = \frac{1}{2}$ deg/sec

$\dot{W}_s = 1/3$ rad/sec^2 $W_s = 2/3$ rad/sec $P_s^2/mI_t = 1.6$ $1 + \lambda = 1.2$

$$\theta_x(p) = \frac{P_x}{P} = 0.625\left[1 + \frac{2.56}{24} - \frac{6.55}{2688} + \frac{16.78}{506880} \ldots\right] = 0.693°$$

$$\theta_y(p) = \frac{P_y}{P_s} = 0.625\left[-\frac{1.6}{2} + \frac{4.1}{240} - \frac{10.49}{54560} \ldots\right] = -0.489°$$

Total momentum displacement

$$\theta(p) = \sqrt{\theta_x^2 + \theta_y^2} = 0.85°$$

The location of the $\hat{k}$ spin axis may be determined by $\hat{k} = \frac{\dot{P}}{m}$

$$\theta_x(\hat{k}) = 1.25\left[\frac{5.12}{24} - \frac{26.2}{2688} + \frac{100.68}{506880} \ldots\right] = 0.255°$$

$$\theta_y(\hat{k}) = 1.25\left[-\frac{1.6}{2} + \frac{12.3}{240} - \frac{52.45}{54560} \ldots\right] = -0.938°$$

For small angles, the nutation half angle may be determined by taking the difference of the component angles

$|\theta_x(N)| = 0.438°$ $|\theta_y(N)| = 0.449°$

Nutation half cone angle $\theta(N) = 0.628°$

Since torquing will continue for another 28 seconds to reach a final spin rate of 10 rad/sec, there may be some additional movement of the momentum vector; however, it should be an order of magnitude less than the initial error of the first few seconds. Taking into account the drift error accumulation from separation to spinup (0.25°), the total pointing error becomes

$\theta(p) = 1.06°$

$\theta(N) = 0.63°$

Error Caused by Spin Jet Misalignment - This error and the remaining errors to be discussed are derived from Reference JPL TR-32-644. The displacement of the angular momentum vector is

$\theta(p) = K_3\gamma + K_4 W_s$

$\gamma = m_t/m_s$ ratio of transverse torque to axial torque caused by jet misalignment

K_3 = coefficient from reference (see discussion below)

K_4 = coefficient from reference (see discussion below)

The coefficient K_4 is a Fresnal integral which is plotted in the reference. Although the computer plot in the reference is with respect to some specific vehicle parameters, they are combined in a manner such that the curves may be normalized and applied to all vehicles. The coefficient K_3 is a double Fresnal integral which does not yield to attempts to normalize; however, the value of K_3 is bounded and approximate solutions may be obtained.

Subsequent to the delta velocity impulse event, the attitude control subsystem maneuvers to the final orientation. The accuracy of the final maneuver is a function of the sensor reference and is required to be two or three degrees depending on the specific mission.

Velocity Dispersion - The velocity dispersion caused by coning occurs because of two sources: initial nutation and misalignment of the delta velocity thrust vector. The error due to nutation is

$$\theta(V,N) \approx \frac{\theta_o(N)^{\pi}}{W_s t_F} \quad W_s t_F > 4\pi$$

$\theta(N)$ = initial nutation

W_s = spin velocity

t_F = period of thrusting

The thrust misalignment error is developed in the reference Eq [67] and is based on the usual Euler angle approximations. This equation is subject to interpretation and does not agree with results of computer simulation and other approximations. An estimate of this error based on several approximate methods is

$$\theta(V,F) = \frac{Fr}{2\lambda I_s W_s^2}$$

r = moment arm (offset) of thrust

Attitude Maneuver - Probe studies at Martin Marietta have considered a number of attitude control systems appropriate to probe missions. The fundamental ACS problem here is to enable a probe to fire a delta velocity impulse and then orient the spin axis to the entry attitude without contact or supervision from the spacecraft or ground station. The economy of the design is a strong influencing factor for system selection. Methods considered consisted of stored momentum systems, offset thruster or radial thrusters to enable separation in the entry attitude, and open loop systems. None of these were feasible or sufficiently accurate and reliable for this application. Two approaches received more serious consideration.

ACS Design - Simple Closed Loop - Single-Axis Maneuver - This approach uses a sun sensor that provides a measurement of solar aspect as well as Sun crossing time. The maneuver sequence would consist of firing a preprogrammed set of precession impulses immediately following the delta velocity impulse maneuver. These

pulses could be offset in phase so that essentially a two-axis maneuver could be achieved, although only the maneuver angle with respect to the Sun line (i.e., solar aspect angle) could be measured. Subsequent to the initial maneuver, some time (order of several hours) would elapse while the damper removed residual nutation. A measurement of solar aspect angle would then provide information for further maneuvers.

ACS Design - Closed Loop - Two-Axis Maneuver - This design approach makes use of a Sun sensor to measure solar aspect angle and Sun crossing time, and a Jupiter sensor to measure Jupiter crossing time. The sequence of the maneuver would be similar to the single-axis system described above. Immediately following the delta velocity impulse maneuver, a preprogrammed series of pulses would orient the probe near its final position. Then, after a waiting period of several damper time constants, measurements are made of solar aspect angle (clock angle) and the angle between the Sun and Jupiter measured about the spin axis of the probe (cone angle). These measurements are then used to develop subsequent precession programs to finalize the probes position. Because of residual nutation, it is not considered desirable to continuously drive the probe to minimize the final error. For this reason the maneuver will take place in a series of steps as described above. With this approach there are certain constraints on the relative position of the Sun and Jupiter as discussed below. This system, using attitude sensors may also be used to trim probe attitude before the delta velocity impulse. Since it represents a minor increment in complexity over a single-axis system and has inherent greater flexibility and capability, it has been the system that has received the major consideration. For missions in which the single axis system may be considered a preferred choice, it would be a minor consideration to reduce the two-axis maneuver system to a single-axis maneuver system.

Application of this approach to the Saturn mission does not require modification of the system although the stored maneuver angles would be changed. The Uranus mission would require some change in functional procedure since the Sun is only 4° away from the spin axis when the probe is in the entry attitude. The system for the Uranus mission will be programmed to point the spin axis directly at the sun initially. The 4-deg maneuver to the final position will then be implemented by sector logic control based on a Uranus sensor pulse. Control of the magnitude of the maneuver will be open loop, i.e., the number and duration of the attitude impulses will be preprogrammed. Because of the small angle of the maneuver, little error may be expected.

Reference System Geometry - The reference system for the probe attitude control consists of the spin axis, the Sun, and a planet. The geometry is illustrated in Figure F-1. The solar aspect sensor measures the angle (α) between the spin axis and the Sun-probe line. The location of the spin axis on this surface is then determined by measuring the angle (β) between the spin axis/Sun plane and the spin axis/planet plane. This measurement is influenced by the planet/probe/Sun angle (ϕ) for which *a priori* knowledge is programmed into the probe. The angle θ locates the probe on the conical surface and may be determined by the following relationship.

$$\tan \beta = \frac{\text{Sin } \alpha \text{ Sin } \theta}{\text{Sin } \alpha \text{ Cos } \theta \text{ Cos } \phi - \text{Cos } \alpha \text{ Sin } \phi}$$

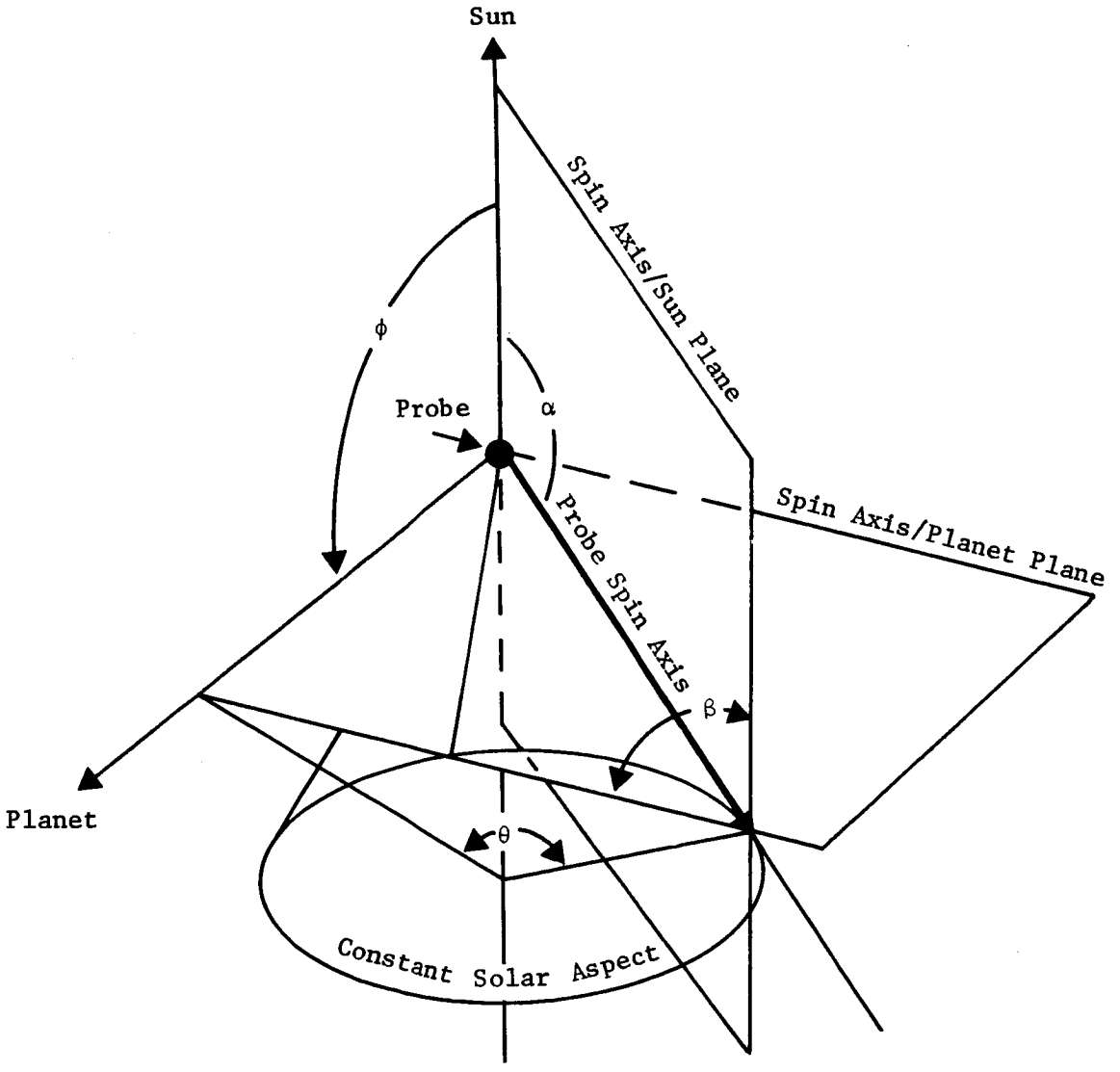


Figure F-1 Reference System Geometry

The angle θ would not be evaluated in the probe because with knowledge of ϕ and α, the measurement of β would be compared directly to a predetermined stored value. When the probe-planet vector lies within the conical surface, θ is a double valued function (i.e., there are two positions on the cone which will result in equal values for β). This could occur during trim maneuvers prior to velocity impulse thrusting. However, the two values of θ are sufficiently far apart not to constitute a problem. For the entry attitude, this condition does not occur. Another undesirable condition occurs when the Sun/probe vector approaches the spin vector as it does in the Uranus mission profile. This represents a singularity in the control processing and creates a sensing problem caused by the finite width of the sensitive angle of the sensor. A slightly different approach must be used on the Uranus mission, as discussed.

2. ACS - Design - Sensors

The problem is the three-axis attitude determination for a spin-stabilized spacecraft at approximately 10^7 km from Jupiter. In the missions discussed, the probe is relatively near the line between Jupiter and the Sun. Jupiter will be nearly full-phase with approximately 0.4 degrees apparent diameter, as seen from the probe. Accuracy of angular measurements within 0.5 degrees is considered adequate.

The design approach uses two sensors: one to obtain two-axis information from the Sun, and the other to furnish third-axis information by sensing Jupiter.

The Sun sensor will measure the angle between the spacecraft spin axis and the Sun. This can be a 9-bit digital output (with the Adcole Corporation instrument), or linear analog output (with the Honeywell Radiation Center instrument). The second axis is determined by the direction of the Sun when the plane containing the instrument's optical axis and the spacecraft spin axis crosses the Sun. This is indicated by a pulse output from the Sun sensor. This sun sensor and its electronics will weigh a maximum of 3.5 lb with a maximum power requirement of 2 watts, if the instrument is to cover the whole celestial sphere on each revolution about the spacecraft spin axis. These numbers can be lowered, if miniaturized integrated circuitry is used, and if the spin-axis-to-Sun angle is constrained within certain limits.

3. ACS Design Jupiter Sensor

The electromagnetic radiation emanating from the planet Jupiter, consists mainly of the following three classifications:

1) Reflected light from the Sun, essentially in the wavelength and from 0.3 to 1.5 microns, with peak at approximately 0.5 micron. This is in the visual and near-infrared region. The apparent shape of Jupiter in this radiation will vary from thin-crescent to fully illuminated disc, as a function of the phase angle between the line of sight from the instrument to Jupiter and the line from Jupiter to the Sun.

2) Energy radiated by the planet, as a "black body," resulting from its own temperature. Since Jupiter has a significant atmosphere and a high rotational speed (approximately 10 hours per revolution), the temperature over the entire apparent surface of Jupiter is relatively constant at approximately 130 °K. Its black-body radiation is essentially in the wavelength band from 5 to 30 microns, peaking at about 11 microns; it is relatively constant from about 8 to 14 microns. Jupiter's apparent shape in this radiation will be the nearly circular shape of an oblate spheroid.

3) Radio-frequency radiations in the wavelength band longer than 3 centimeters. This radiation seems to be associated with varying but discrete sources on the planet, and is therefore not suitable for sensing the planet for determination of its center.

Sensors that can detect the reflected solar radiation are many, and their relative usefulness depends upon the specific purpose of the instrumentation as well as their own intrinsic properties. Some of the more frequently used materials are tabulated.

At least three materials are sensitive in the range of Jupiter's black-body radiation: mercury-doped germanium, operating at 28 °K; gold-doped germanium, at 60°K; copper-doped germanium, at 4.2°K. Zinc-doped germanium at 4.2°K covers the desired range at lower sensitivity; it is more useful at somewhat longer wavelengths. The disadvantage common to these materials is that they must be operated at very low temperatures. This often adds prohibitive amounts of weight for spacecraft applications, but the lower temperatures available in space can conceivably be used to advantage for these detectors.

Material	Wavelength at Peak Response (μ)	Remarks
S-1	1	
S-11	0.3	
S-20	0.42	Highest response
Others		
Silicon	1	Photo conductive and photovoltaic
Selenium	0.8	
Gallium arsonide	0.8	
Copper-cupric oxide	0.5	
Cadmium sulphide	(visual)	

Based on the above, the device selected for a Jupiter sensor will consist of a silicon sensitive element and possibly a lens system.

The Sun sensor requirements for the Saturn mission appear to be within the requirements of available sensors. At Uranus distance from the Sun, an additional lens system may be necessary. Planet sensors for Saturn and Uranus will require additional lenses as compared to the Jupiter sensor; however, these sensors have a very simple function and the modification would be minor.

4. ACS Design - Electronics

The functional block diagram illustrated in Figure F-2 is representative of the electronics for all missions requiring an attitude control system. The functions required of the ACS electronics follow.

1) Process the solar aspect angle information. The data output of the solar aspect sensor is generally analog or digital gray code. In either case, this output should be converted to binary digital for processing in the logic. The solar aspect output may be used as a measure of nutation as described in the paragraph on logic.

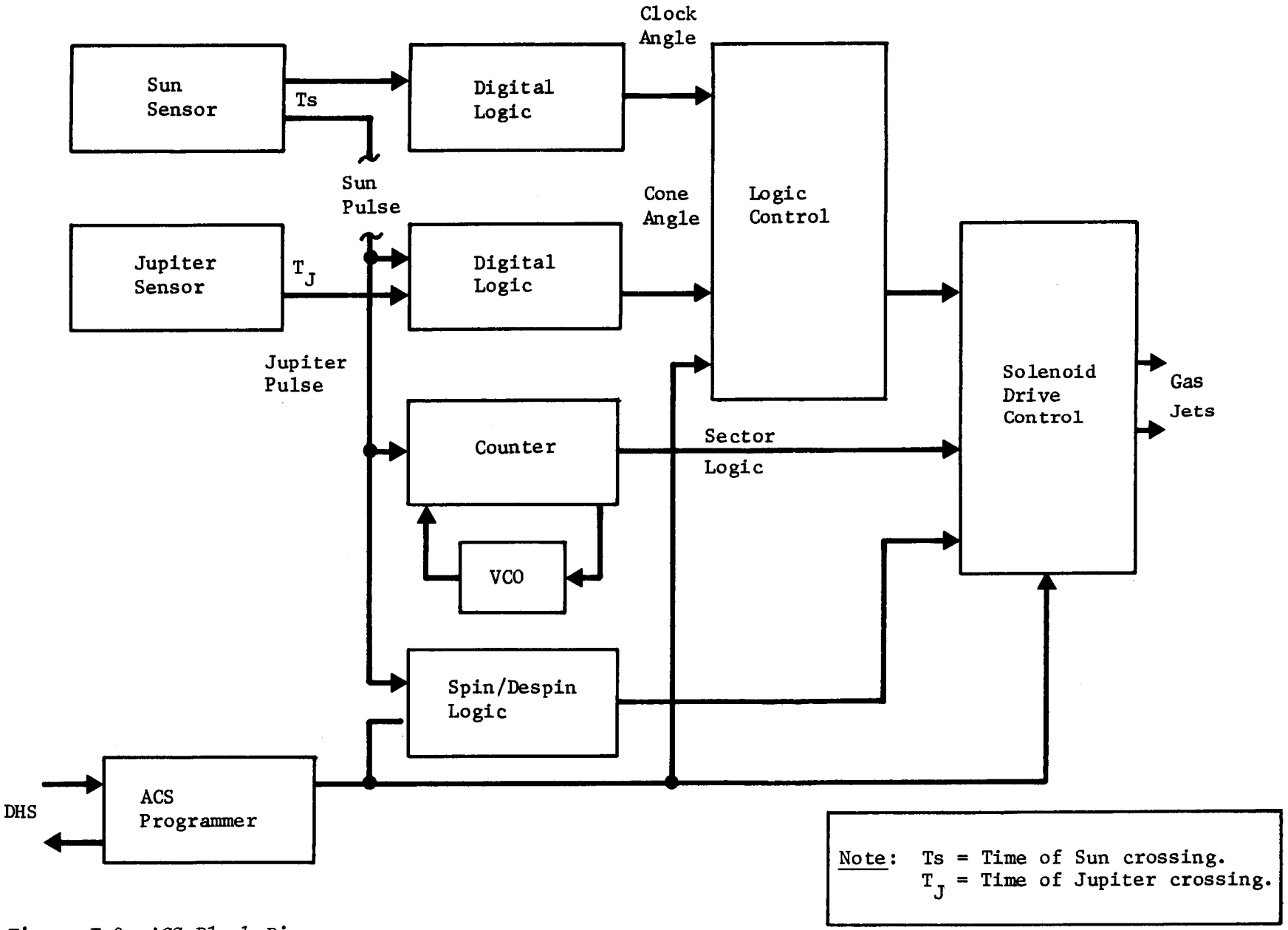


Figure F-2 ACS Block Diagram

2) The pulse output from the Sun sensor is generated when the Sun crosses the sensor's optical axis. Processing of this pulse will consist of establishing the center of the pulse by selecting the point at which the derivative (slope) is equal to zero (maximum amplitude) or averaging the time between preselected amplitudes. Some study must be made of the effect of the greatly increased solar range on this pulse. It is distinctly possible that the solar intensity near Jupiter may be decreased by factors other than range as recent data from the Mariner flights indicate a discrepancy between measured and expected illumination. The Sun pulse is used to control the sector logic (discussed below) as well as provide attitude information in combination with a similar Jupiter pulse.

3) The pulse derived from the Jupiter sensor when the planet crosses the optical axis of the sensor is essentially similar to the Sun pulse described above and processing will be the same.

4) Sector logic will be used to establish correct precession jet firing intervals. There are two obvious approaches to this logic. A counter may be used to measure the period of revolution. Simple binary division and addition processing may then be used to establish the angular position of the probe at any time during the next revolution on the basis of the content of the register. Since the measured period of rotation will be updated every revolution, the basic timing oscillator would have no critical nominal frequency requirements and reasonable drift requirements resulting in a simple economical design for this element. However, the digital processing would be increased over the voltage controlled oscillator approach. The use of a VCO would enable the sector logic to be hard wired. This system generates the proper sector logic by driving the oscillator so that the count register approaches a fixed value for every revolution. The angular position of the probe is determined when this counter reaches a preset value. This is the preferred approach for this function since the required development is decreased.

5) A nominal functional block diagram of the solar aspect precessing is shown in Figure F-3. At predetermined intervals, a series of solar aspect angles will be measured and the maximum and minimum selected. This is necessary since nutation will be present if the difference between these angles is too great, indicating excessive nutation an another mating interval will be initiated. If the difference between the maximum

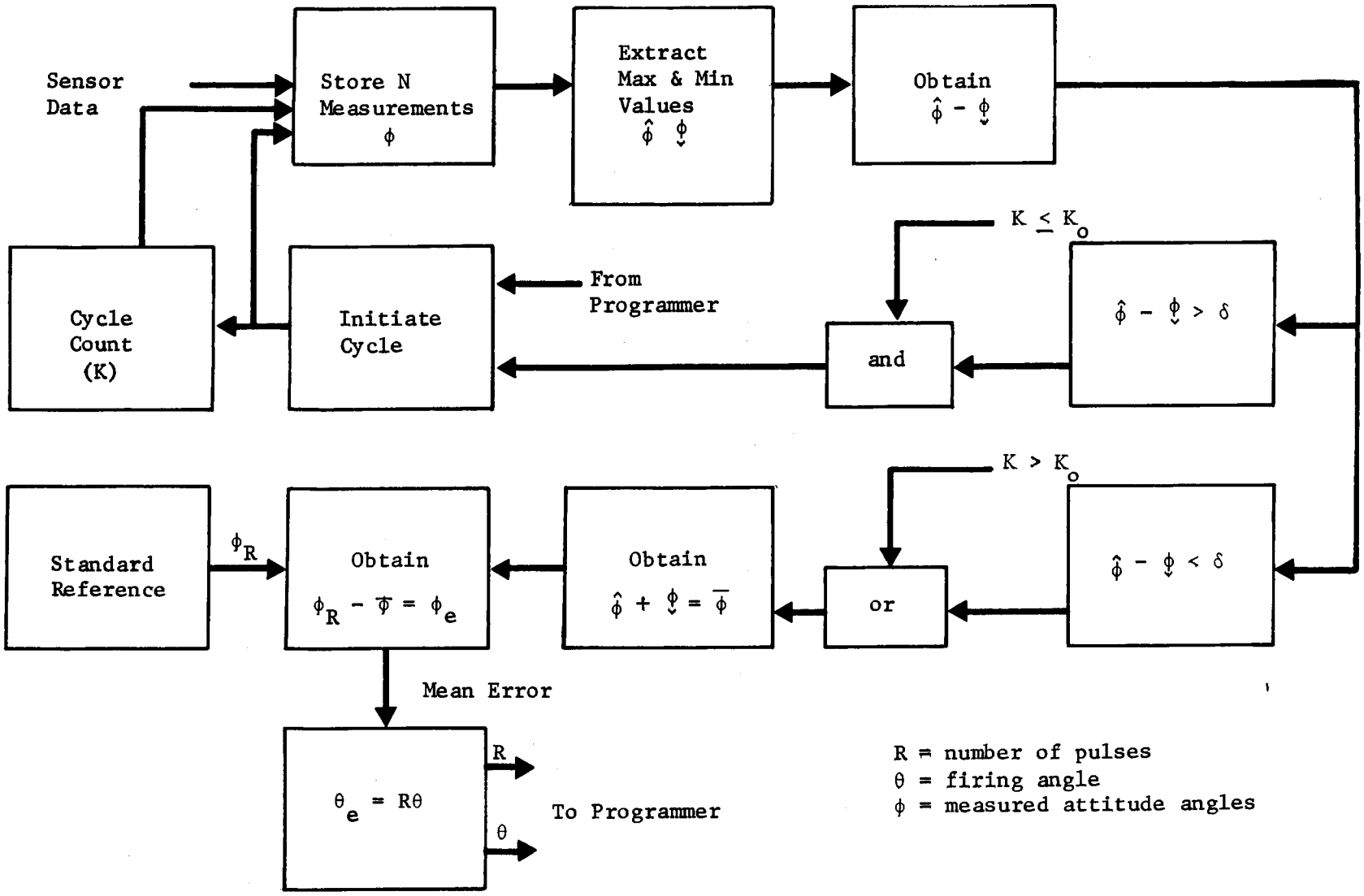


Figure F-3 Precession Logic

and minimum angle is sufficiently small, the attitude evaluation will be performed. The evaluation will consist of summing the maximum and minimum measurements to obtain a measurement related to the mean value which is representative of the position of the angular momentum vector. This value is then compared to a preset attitude command and the sign and magnitude of the error is established. A similar function provides an evaluation of the spin axis cone angle. The difference in the content of the revolution period count register between the Sun and Jupiter pulse is compared with the total revolution period. This provides a measurement of the angle (β) through which the probe rotates between pulses, and establishes the position of the probe on the space cone defined by the solar aspect angle. An averaging similar to that provided by the solar aspect logic is performed and the results compared with a present command. The resultant angular errors are then used to program the timing of the precession events and pulse width. When the indicated error decreases below the allowable maximum error, the ACS signals the data management system that the maneuver is complete and the pre-cost shutdown sequence is initiated.

The attitude control logic may be implemented by COSMOS if the state of the art permits. Since this is a critical maneuver, and with this design there is no method by which the success of the maneuver may be evaluated and readjusted by spacecraft or ground command, it is recommended that 100% redundant majority logic be used. The use of COSMOS will alleviate the power penalty that might otherwise be incurred. The Jupiter range at which this maneuver takes place is sufficient to ignore the effects of the Jupiter radiation belts.

The precession pulses will be implemented by pneumatic jets driven by appropriate power amplifiers. The design of these amplifiers should be such that they require low power during the standby conditions.

The required vehicle maneuver is relatively simple and consequently the electronics presents no design problem. Some further studies may be required to evaluate the effects of nutation on subsystem performance.

ACS Design - Damper - A viscous ring damper was selected because of its mechanical simplicity and its advantages of no mechanical moving parts, no threshold of performance, insensitivity to change in spin rate, mass properties and temperature, and it does not effect probe static or dynamic balance, or have critical mounting

or geometry requirements. Its principal disadvantages are size and weight which are inversely related to rather long-time constants. In the eventuality that the viscous ring damper proves impractical, a tuned wheel which is much smaller but would increase cost may be used. The performance of the viscous damper has been analyzed and the time constant is given by

$$\tau = \frac{2\pi I_s}{F(\gamma) m R^2 (1 + \lambda)^2 W_s}$$

I_s = spin moment of inertia

I_t = transverse moment of inertia

$F(\gamma)$ = function of wobble Reynolds number 1

m = mass of fluid

R = radius of ring

$= I_s/I_t - 1$

W_s = angular rate of probe

With the constants appropriate to the various probes with dynamic attitude control, it appears that time constants of the order of one hour are feasible with a 12-cm diameter damper. Since the period during which the ACS system needs to be active may be as long as six hours, this would appear adequate. With a vehicle operating at 5 rpm, the damping period would extend out to twenty hours. This does not present a problem since there is no attitude control system dependent on the damping on missions with this vehicle angular rate. Furthermore, initial nutation would be due only to tipoff rates and approximately seven days are available for damping.

5. Summary and Results

The structural tolerances used in evaluating disturbances to the probe are listed.

Structural Tolerances (3σ)

Nozzle/flange, cm	0.0254
Flange, cm	0.0762
Mounting surface, deg	0.1
Cg location, cm	0.038
Thrust vector, deg	0.1
Axial thrust offset (RSS) cm	0.144
Spin Thrust offset (RSS) cm	0.102

Probe Parameters

Spin rate, W_s, rad/sec	10 (0. 5 Pioneer mission)
Spin torque, m, Newton-Meters	4.07
Spin inertia, I_s, kg-m^2	12.2
Thrust, F, Newtons	810
Thrust period, t_F, sec	15
Tipoff rate, W_t deg/sec	0.5
Drift period, t_D, sec	0.5
$I_s/I_t - 1$	0.2

Error Source		Value (deg)
1. Tipoff error (at 0.5 rad/sec)	$\frac{W_t I_t}{W_s I_s}$	0.8
2. Drift error	$W_t t_D$	0.25
3. Spin-up (tipoff error) (P vector)		0.85
4. Combined 2. & 3.		1.06
5. Spinup (tipoff error) (nutation)		0.63
6. Spinup (misalignment) (P vector)		0.125
7. Spinup (misalignment) (nutation)		0.125

Error Source		Value (deg)
8.	Combined 5. & 7. (nutation) RSS	0.66
9.	Velocity dispersion (nutation)	0.014
10.	Velocity dispersion (misalignment)	0.902
11.	Velocity dispersion (combined 9. & 10.)	0.905
12.	Velocity dispersion (combined 11. & 4.) RSS	1.39
13.	Velocity dispersion (combined 11. & 0.5 deg ACS error) RSS	1.040

Items 13 and 12 express expected errors with and without an ACS trim maneuver before delta velocity impulse thrusting. The velocity dispersions have significant effects on trajectory dispersions and result in higher communication power and longer acquisition time. Since one degree is the nominal error budget contribution of this subsystem to the velocity dispersion, the trim maneuver is included in the mission profile

The tipoff rate specified is not necessarily critical if the trim maneuver before delta velocity thrust is included in the mission sequence or the mission uses the spacecraft deflect mode. The value $\left(W_T = 1/2 \text{ deg/second}\right)$ was selected based on expected and present state of the art. Vela I, II, III, and IV, and OGOI (launches 1963/1964) apparently achieved near this capability at higher separation rates with the use of matched springs. This design parameter is discussed in more detail in Volume II, Section V.B.11 of this report.

APPENDIX G

ELECTRICAL POWER AND PYROTECHNIC SUBSYSTEMS ANALYSIS

E. A. Berkery

June 9, 1972

ELECTRICAL POWER AND PYROTECHNIC SUBSYSTEMS

Power requirements for the probe components are listed in Table G-1. The subsystem design approach for all missions is essentially the same. The functional block diagram of the power and pyrotechnic subsystem is illustrated in Figure G-1. It should be noted that there are two power subsystems: (1) post separation power subsystem consisting of a primary power source, power conditioning, and essentially hard wire distribution; (2) entry power subsystem consisting of a primary power source, separation power filters, and relay power distribution. In addition to the above, there are two long-life low-drain Hg-Zn batteries to provide power for the Accutron timer and the initial preentry pyrotechnic event. The power and pyrotechnic subsystem configuration was based on an evaluation of a study of outer planet probe requirements. Batteries were evaluated on the basis of a nominal Jupiter mission time and temperature profile; this evaluation would not be valid for the application of secondary cells to Saturn and Uranus. Primary batteries were selected and will fly in the dry state until used. The evaluation for the remote activated cells is considered valid for Saturn and Uranus.

Table G-1 Nominal Power Requirements

SUBSYSTEM ELEMENTS	POWER(W)	SUBSYSTEM ELEMENTS	POWER(W)
Data Management	6.9	ACS Electronics	2.0
Memory	12.0	Sun Sensor	2.0
Pyrotechnics	0.5	Planet Sensor	1.0
Instrument Engineering	1.0	Mass Spectrometer	14.0
Vehicle Engineering	1.0	Accelerometer	2.8
Accutron Timer	14 μ(a)	Temperature Gage	1.4
Nutation Damper	(b)	Pressure Gage	1.3
RF Subsystem	14-122		

Power Subsystem Efficiency		(a)	Self Contained Hg-Zn Battery
Postseparation	80%		
Entry	90%	(b)	No Power Required

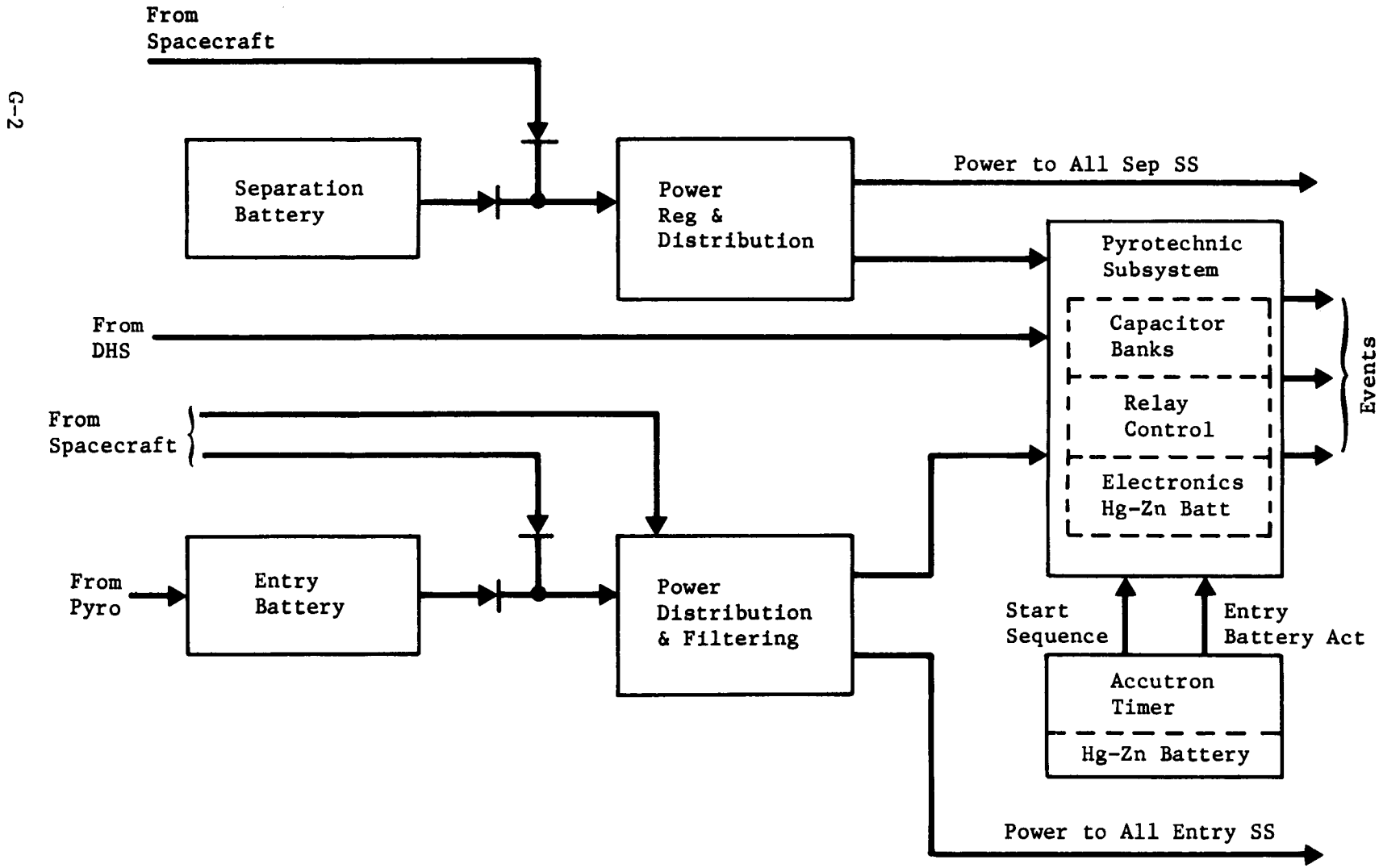


Figure G-1 Power & Pyrotechnic Subsystems

A. POWER SUBSYSTEM

1. Postseparation Power Subsystem

This subsystem provides power for the attitude control, data handling, and pyrotechnic subsystems for the approximate 6-hr post-separation period allowed for the probe attitude control maneuver. The power subsystem consists of a power source, conversion and regulating equipment. It is activated by the spacecraft before separation. The subsystem will also be activated by spacecraft power during preseparation checkout.

2 Entry Power Subsystem

This subsystem provides power to the data handling, communication, science, and pyrotechnic subsystems. The distribution system consists of relays and power-isolation filters to deliver unregulated battery power to various components. Power conditioning and regulation will be implemented in the individual components as required. This approach is used for the entry configuration to minimize the possibility of common-mode failure and to permit use of lower-power transistors that tend to be less sensitive to radiation.

3. Power Source

There are three fundamentally different power source requirements: Probe bus power source, Accutron timer power source, and preentry pyrotechnics power source. Power for the Accutron timer is provided by a Hg-Zn battery which is required to supply approximately 8 microamperes at 1.6 volts for 30 days. A 40-volt Hg-Zn battery is required to charge two pyrotechnic capacitor banks, hold the charge against leakage for approximately twenty minutes, provide power to operate two or three (detail design dependent) latching relays and some minor pyrotechnic logic. Initial drain of the 40-volt Hg-Zn battery is expected to be approximately 40 milliamperes, dropping rapidly to less than one milliampere as the capacitors charge and leakage decreases. The current will rise again to approximately 10 milliamperes for a fraction of a second at the end of the 20-minute soak period. The Hg-Zn battery size and weight are based on standard catalog cells degraded at 7% per year. Approximately 15% increase in volume and weight was allowed for packaging. The Hg-Zn batteries are located near the RTG heaters where the temperature control is more effective and protection against loc temperature conditions is provided. The probe bus power source is required to meet much higher power requirements but has an active life of less than 6.5 hr. Selection of battery type to supply probe power is discussed below.

4. Probe Bus Power Source

Although consideration has been given to various power sources such as RTGs, solar cells, and gas generators for the probe, the choice rapidly narrows to some type of battery. An evaluation of various types has been made and is based on the following mission/test profiles.

1) Ni-Cd Secondary - Discharged (Table G-2)

   a) Fly discharged 526 days at 50 to 80°F

   b) Condition battery at C/10 or greater

   c) Hold open circuit at less than 70°F for 20 days

   d) Discharge between 40 and 110°F for 2 hours or less

   e) System design to 80% depth of discharge

2) Ni-Cd Secondary - Charged

   a) Float charge for 526 days at C/100 or greater (loss of 40% expected at temperatures less than 68°F)

   b) Hold charged on open circuit at less than 70°F for 20 days

   c) Discharge between 40 and 100°F for 2 hr or less

   d) System design to 80% depth of discharge

3) Ag-Zn Remotely Activated - Conventional Design

   a) Assume two batteries, postseparation battery (6-hr life) and entry battery (40-min life); tubular-reservoir standard gas generator activator; common manifold fill

   b) Standard design capable of satisfying requirements for up to 24-hour activated life.

4) Ag-Zn Remotely Activated - Pile Construction

   a) Assumptions as above, but diaphragm activator mechanism

   b) Design capable of satisfying requirement for 6-hour activated life; some development needed if activated life is to be significantly extended.

5) Ag-Zn Secondary (Table G-3)

   In all probability, the only cell design that meets the requirement requires irradiated and cross-linked separator

Table G-2 Ni-Cad Secondary Battery (Float Charge)

Cell Type Rsn#	Cell, amp-hr	New Cells, watt-hr	New Cells, watt-hr/lb (80% DOD)	Degraded watt-hr/lb Discharge/Cruise 20% pkg Wt	Degraded watt-hr/lb Float Charge 20% pkg Wt
3	3.2	84	8.1	6.5	3.2
6	6.0	168	9.3	7.4	3.7
8	8	224	8.1	6.5	3.2
9	9	252	8.8	7.0	3.5
12	12	336	10.0	8.0	4.0
14	14	392	10.0	8.0	4.0
15	15	420	9.1	7.3	3.6
20	25	700	10.4	8.3	4.2
21	20	560	10.1	8.1	4.0
22	22	616	10.6	8.5	4.2
36	36	1010	12.3	9.9	4.9

Note: Basis of Curves for Figure G-2 (Eagle Picher Cell Design 28 volt, 24 Cell Systems).

Table G-3 Ag-Zn Secondary Battery

Cell, amp-hr	Cells, watt-hr	Cells, watt-hr/lb Rated Cells	Cells, watt-hr/lb New Cells	New Battery, watt-hr/lb	Battery Float, watt-hr/lb	Battery Open CKT watt-hr/lb	Battery D/C Stored watt-hr/lb
.8	22	24	31.2	25	5.3	12.2	14.5
1.5	42	30	39	31.2	6.6	15.3	18.1
3.0	84	38	49.5	40	8.4	19.6	23.2
5.3	147	42	54.6	43.7	9.1	21.4	25.3
8.0	223	48	62.4	50	10.5	24.5	29.0
11.5	322	50	65	52	10.9	25.5	30.2
20.0	560	60	78	62.4	13.1	30.5	36.2
30.0	480	63	82	65.6	13.8	32.1	38
45.0	1260	66	86	68.8	14.4	33.7	39.9

Note: Basis of curves for Figure G-2.

Probe Power Source Capability

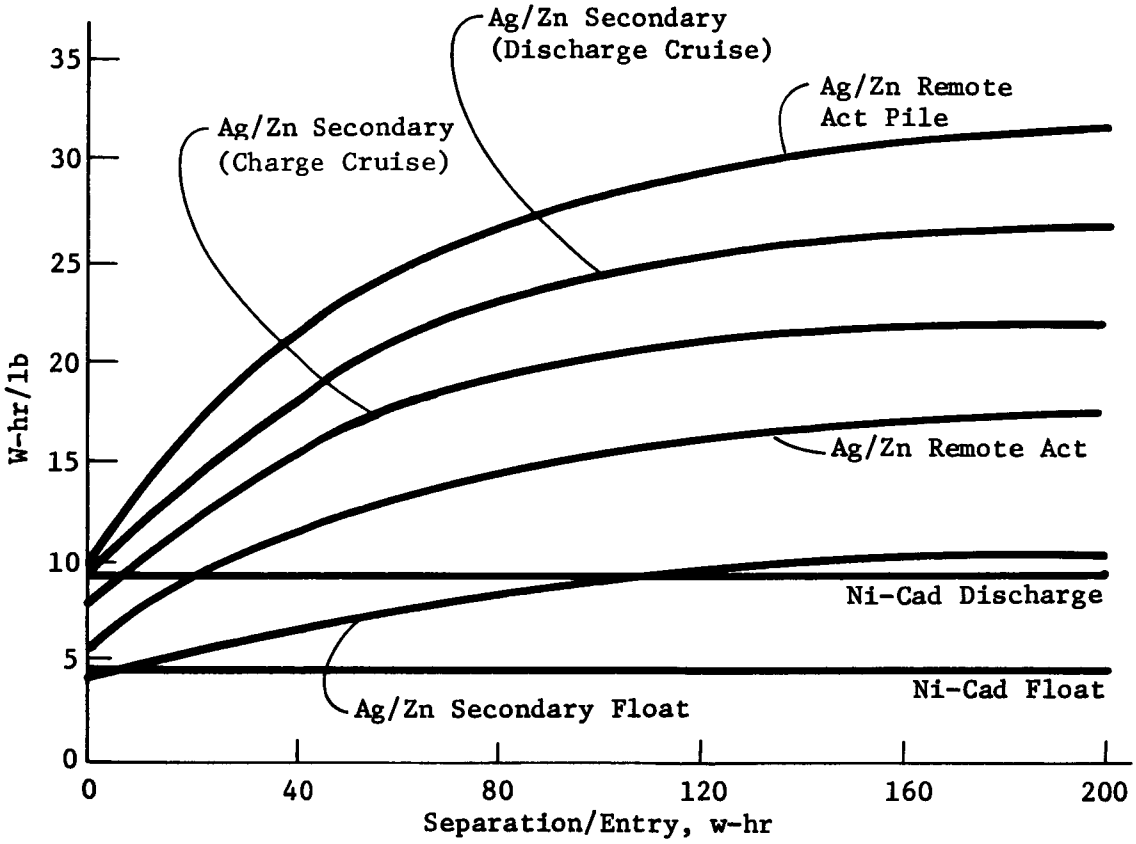


Figure G-2 Power Source Evaluations

material. General Electric Test Report 67SD337(G5) offers the best data to date. Venus Planetary Explorer tests (by Martin Marietta) will be performed on similar cells.

6) Ag-Zn Secondary - Float Charge

   a) High decay rate, expect a loss of approximately 3% per month (approximately 54% total)

   b) During a 30-day charge stand, expect a 5% loss.

   c) System design to 80% depth at discharge

7) Ag-Zn Secondary - Open Circuit Stand

   a) Assumed charge at launch and left open circuit at 50°F for 526 days

   b) Battery would lose all capacity and need recharge

   c) Expect a permanent loss of 26% on recharge

   d) Expect 5% loss during 30-day charged stand.

   e) System design to 80% depth at discharge

8) Ag-Zn Discharge Stand

   a) Expect a loss of 17% on recharge

   b) Expect a 5% loss after 30-day charge stand

   c) System design to 80% depth at discharge

5. Evaluation

Based on the above decay and degradation rates, tests, and Reference 1 and 2, the curves in Figure G-2 were generated. It should be noted that all Ag-Zn secondary batteries would need separator development for this application. The pile construction battery would need known minor modifications and packaging for life beyond approximately 6 hour. The Ni-Cd batteries have the highest reliability but are excessively heavy. With these considerations and the need for critical recharge and conditioning control for secondary batteries, the remotely activated Ag-Zn battery was selected for this application. Consideration of standard versus pile construction indicated approximately 50% weight could be saved with the latter. The state of the art indicates that all development necessary for this application should be completed and available for the pile construction battery by 1975. Based on the above, considerations, the pile construction battery is recommended for this application and the weights indicated in Figure G-2 have been used in the current estimates.

The remote activated Ag-Zn battery requires no significant development to meet the electrical requirements; however, a nine-day unused open circuit requirement subsequent to discharge presents a concern with respect to gassing. Silver-zinc couples generate oxygen and hydrogen during any wet stand operation. Hydrogen is by far the major contributor to the evolved gas and results from thermodynamically unstable zinc in contact with KOH and the negative plate potential being above the hydrogen potential. In addition, internal and external shorts will contribute to the gassing.

The battery design will include the following features to greatly reduce the gassing and also provide the capability of storing the gasses generated to safe internal pressure.

1) Additives to the negative plate - 2-4% mercuric oxide

2) High KOH concentration - 40-45%

3) Ion exhange irradiated separators. For example: Permion 307, to provide 7-day wet stand life

4) Flap valve on each cell that permits activation, but prevents low resistance intercell leakage and allows gasses to filter into the manifold.

The cooling gasses of the gas generator subsequent to activation reduces the working pressure of the battery during discharge below the activator design pressure. The gasses by the cells works into the electrolyte container area pushing back the activator and gradually increasing the internal pressure of the battery. The design pressure will not be exceeded and the battery can be hermetically sealed.

Long-Life Remotely Activated Batteries

An alternative approach would use standard remotely activated batteries with some modifications for longer life. This would

eliminate a significant problem of energizing pyrotechnics after postseparation coast. The degradation and life characteristics are, in general, applicable to all primary Ag-Zn designs. The fill manifold is a development for standard construction.

7. Remotely Activated Ag-Zn Oxide Batteries

Current designs of remotely activated batteries for space application generally employ an electrolyte reservoir separated from the dry cells by a frangible diaphragm. Activation is accomplished by initiating a trigger mechanism or explosive squib that introduces pressurized gas to the electrolyte compartment, thus forcing the electrolyte into the battery cell compartment.

Typically, separator materials used in standard designs are not semipermeable membranes that permit long activated life, but hydrophylic nonwoven materials capable of fast activation. Activated stand life exceeding 24 hours should not be expected.

Dry Stand Loss - Losses usually result from loss of peroxide on the positive, which is accelerated at high temperature. Figure G-3 shows the effect of temperature and indicates capacity, at any temperature, will decay to a mimimum of 50% of rated value, depending on storage time. Dry storage loss is a function of humidity control, temperature, plate processing, and particularly cell materails and fabricating techniques. Most battery manufacturers are aware of these problems and have solved them. Typical data on the Poseidon missile program indicates no loss of capacity during a 91-month storage.

Activated Stand Life - There are two major problems in extending activated stand life of remotely activated batteries.

1) *Electrolyte Paths* - Standard designs use a manifold across the cells that permits simultaneous activation of all cells. After activation, the manifold may remain flooded and, at best, high-resistance electrolyte all paths exist between cells. Resulting potentials between cells are high enough to permit Zn precipitation along the electrolyte paths, resulting in massive shorts and subsequent discharge of the battery.

2) *Separator Material* - Absorbent separators in remotely activated batteries serve two major purposes: activation times of less than 2 sec; higher current density (i.e., voltage current

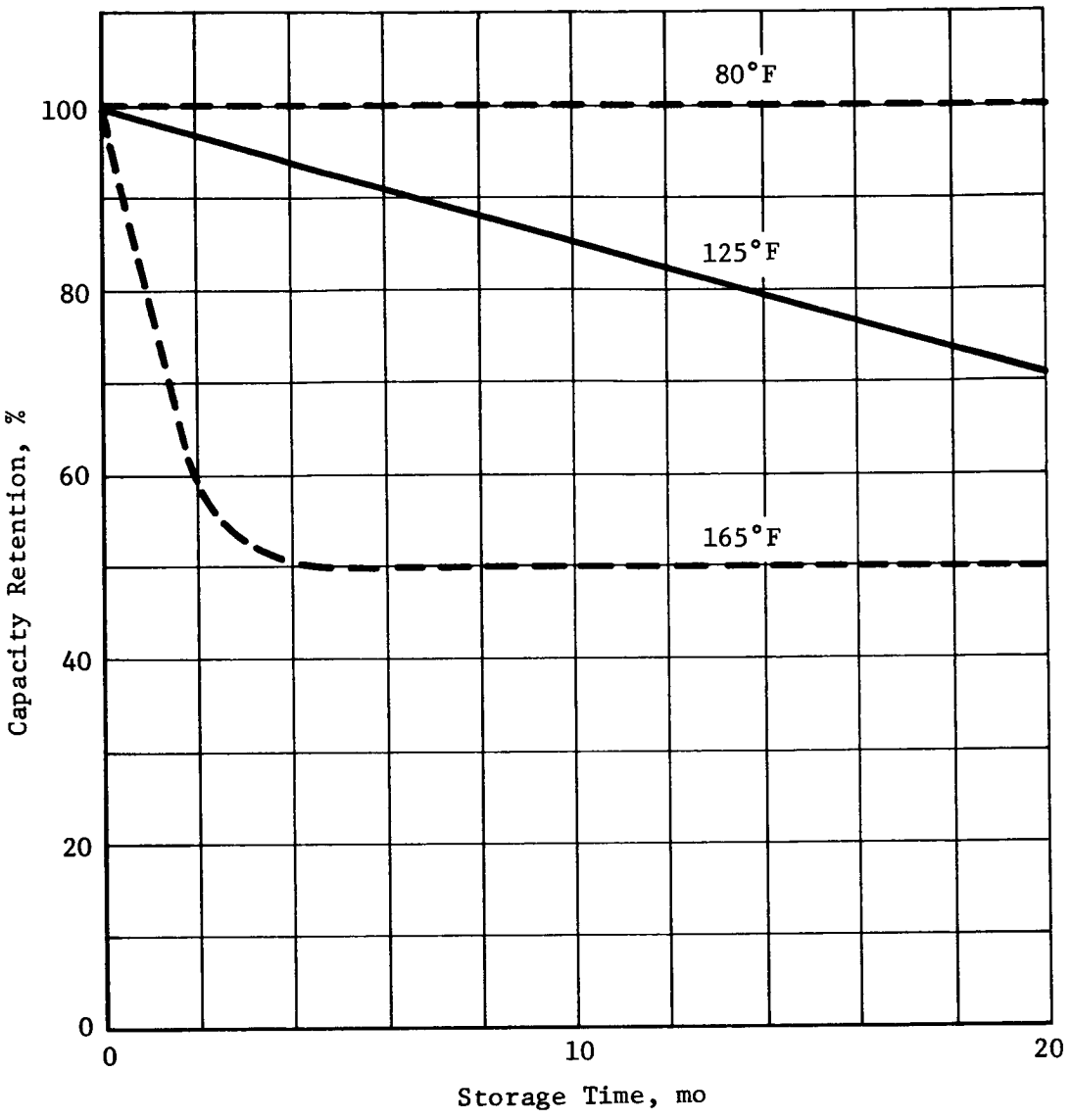


Figure G-3 Dry-Storage Charge-Retention Characteristics

characteristics). The major disadvantage is that it is not a semipermeable membrane and oxidation occurs at a high rate, resulting in self-discharge.

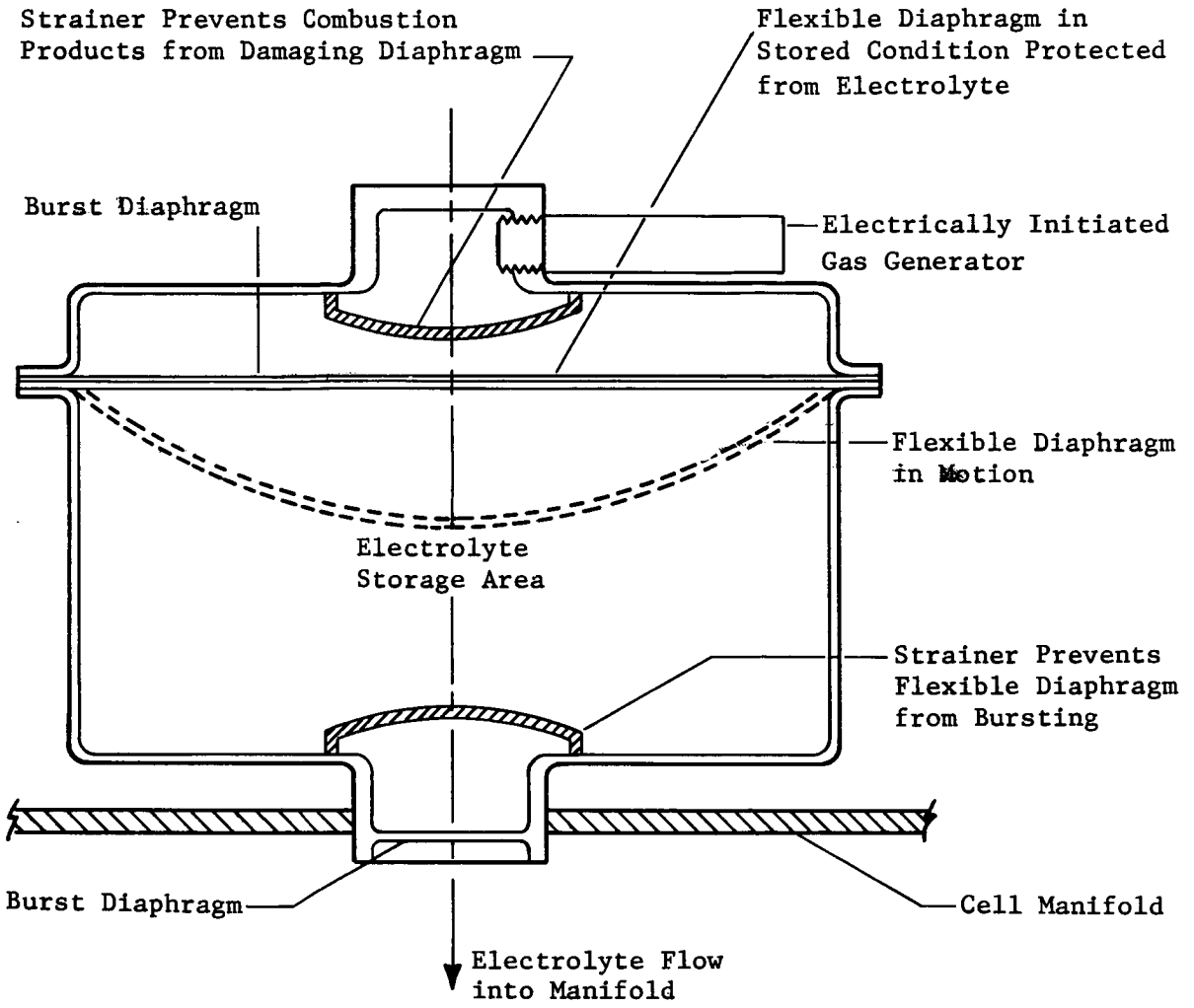
Weight Shift Due to Activation - Upon activation, electrolyte transfers from the reservoit to the cells. The quantity of electrolyte varies with capacity and separator material. As a rule of thumb, 4.2 ml/A-h/cell or 5.9 gm/A-h/cell can be used (e.g., 20 A-h 20-cell battery - 2360 gm KOH. The weight shift depends on the battery design. With a tubular reservoir wrapped around the cell pack, as described in the Eagle Picher data (Ref G-3), electrolyte would transfer from the periphery to the center of the black box. In case of a higher-energy-density design, as shown in Figure G-4, transfer approximates a shift from the top half of the black box to the bottom half.

Design Concepts for Long Wet Stand - A 7-day wet-stand life has been achieved with the design shown in Figure G-5 and G-6. Figure G-5 shows a high energy density design in which the cell case is a half shell. High energy density is achieved by elimination of the double cell wall resulting from normal cell construction. The center wall also can be as thin as 0.0254 cm (0.01 in.).

The half shells are assembled so that the flexible member is directly below the open section. Design tolerances provide a crude seal at this point. When the battery is activated through the manifold, activation pressures deflect the flexible member, permitting electrolyte to enter the cell. At equilibrium conditions, a pressure balance occurs across the flexible member and the joint closes causing very high resistance paths between cells, thus minimizing electrolyte shorts.

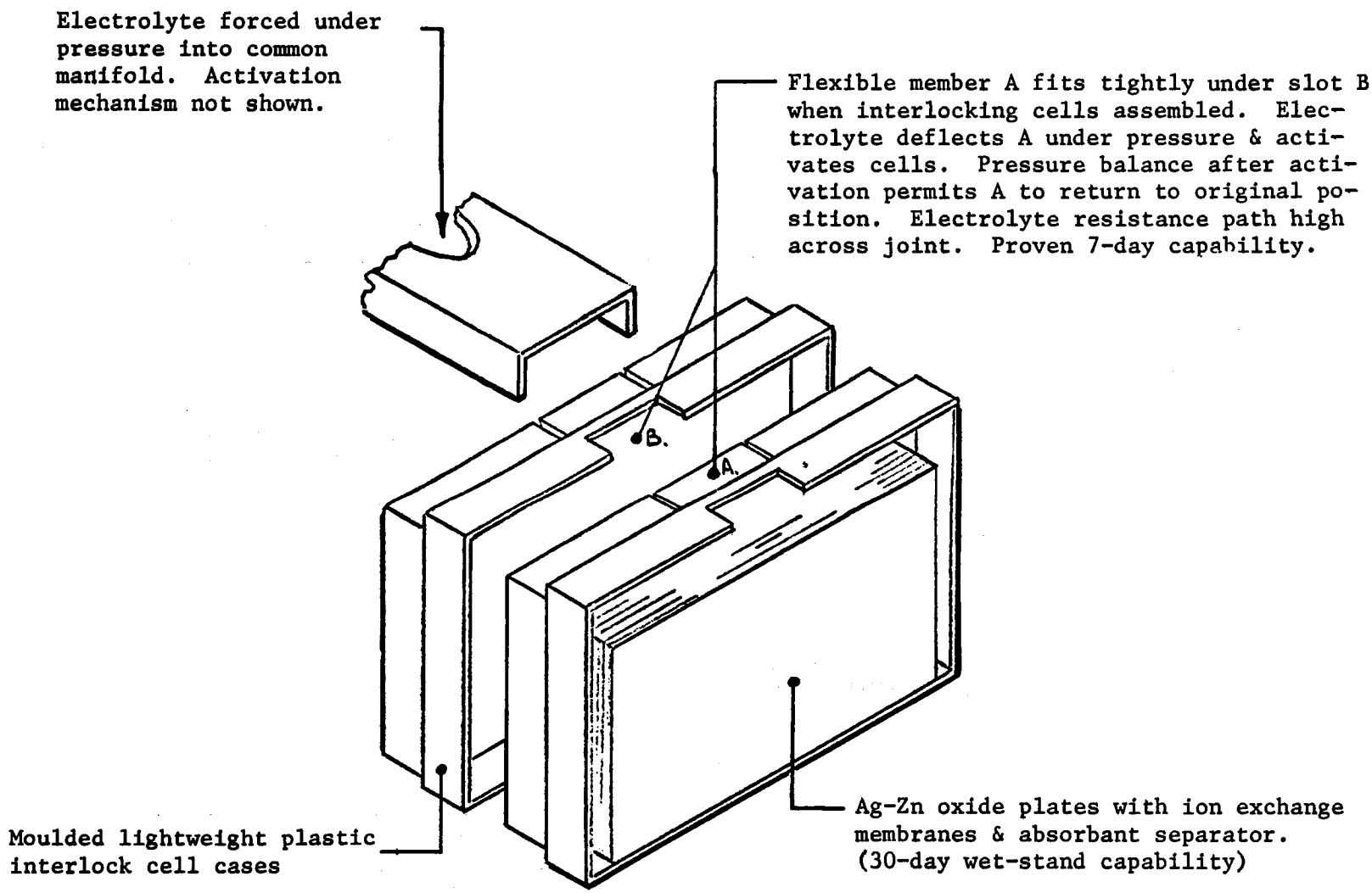
To eliminate cell degradation caused by separator breakdown, a semipermeable membrane would be included in the cell pack. Activation times would increase to 20 seconds and wet-stand life to 7 days.

Figure G-6 shows a more conservative design that increases energy density, but eliminates intercell shorting. Electrolyte enters tube A and the first cell at the level of tube B. It travels up tube B across to the next cell and down tube A of the second cell. This process is repeated until the last cell is filled. Excess electrolyte continues to move into a final compartment where it is centrifuged into an absorbent material. The activation mechanism is designed so activating gasses follow through with the electrolyte



Note:	Gas generated by initiator increases internal pressure of mechanism until burst diaphragms open. Electrolyte flows into manifold under pressure of distending flexible diaphragm.

Figure G-4 High Energy Density Activation Mechanism for Ag-Zn Batteries



Note: System designed & qualified for 7-day wet-stand requirement.

Figure G-5 Remotely Activated 30-Day Wet-Stand Design Concept 1

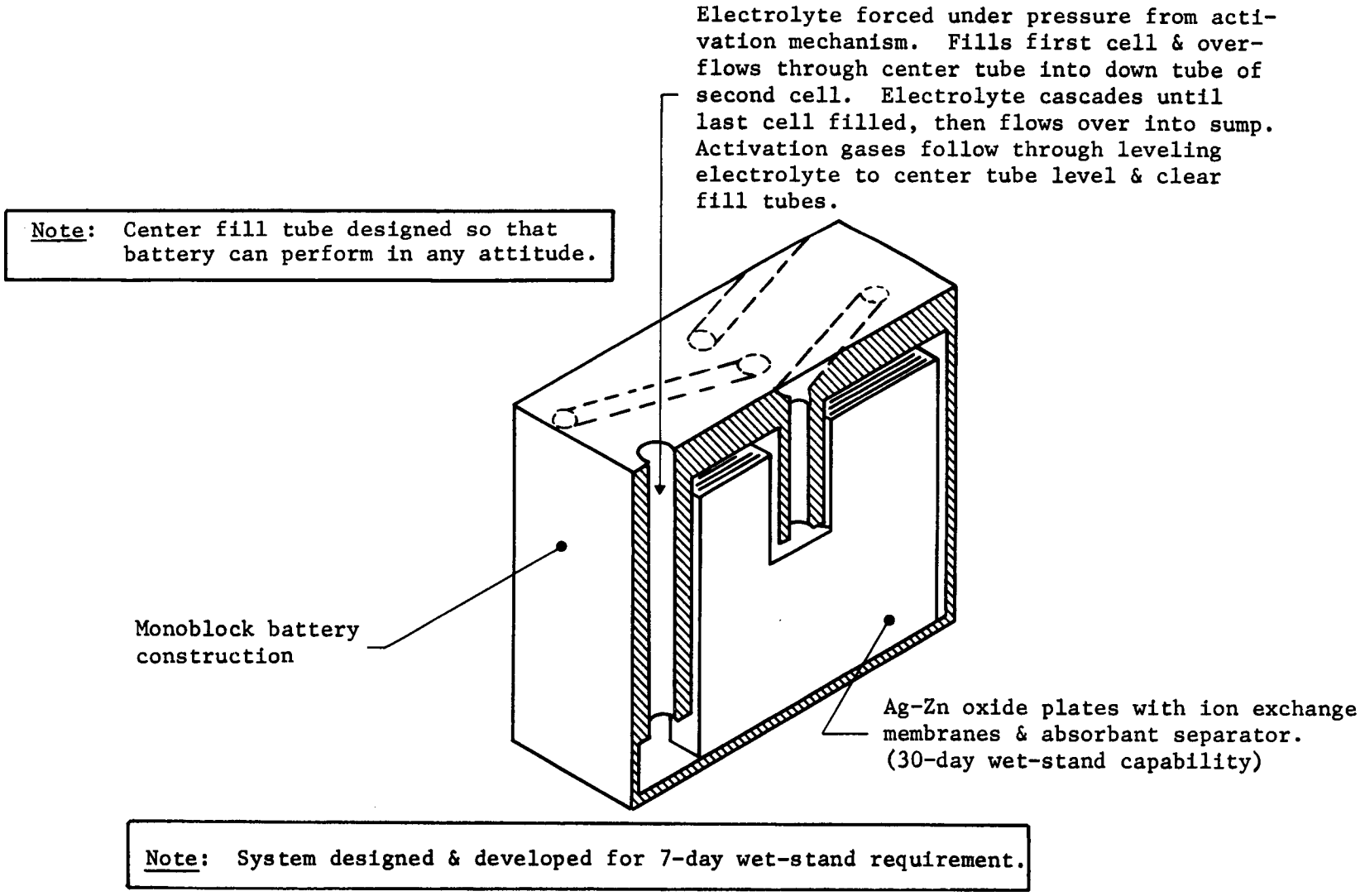


Figure G-6 Remotely Activated 30-Day Wet-Stand Design Concept 2

and purge the tubes and intertell paths of electrolyte. This design, like the other, will operate in any attitude. As before, separator material would be changed to a semipermeable membrane.

Both designs were developed for the Royal Aircraft Establishment, England, for a 7-day activated mission. It is expected that the design in Figure G-6 could exceed this requirement, but a 30-day stand would be a marginal concept. Conceptually, a revised design would be capable of providing a 30-day wet stand with a high degree of confidence.

Watt-Hour Design Margins - If it is assumed that electrolyte leakage paths can be eliminated, and the whole design concept is based on this assumption, the following margins can be applied when sizing the battery.

With up-to-date design methods, a 40 W-h/lb (pile type) battery can be manufactured.

Start with 40 W-h/lb.

Apply degradation rates:

a) Dry stand loss 3% per year below 90°F; it would be undesirable to fly the battery at a higher temperature;

b) Activated stand loss 0.5% per day;

c) If sterilization is required, loss is 25%, with no further loss because of a dry-charged stand.

Items a) and b) can be supported by characteristics of primary Ag-Zn batteries like those used on Titan III and Biosatellite, and torpedo batteries. Item c) causes loss of peroxide, which in a normal design would be 50%. However, because this loss is known, the Zn plate capacity would be reduced accordingly, and the weight gained would be transferred to the positive plate.

Temperature Performance Activated - Normal operating temperatures should be 30 to 80°F. However, if load requirements are known, the battery could be designed to perform at lower temperatures around 10°F. The high-temperature restraint is not required on discharge, but has a degrading factor on the stand.

B. PYROTECHNIC SUBSYSTEM

The pyrotechnic subsystem is similar to designs already applied to several space vehicles such as Mariner and Viking. Specific

constraints and devices considered for outer planet probe designs were principally derived from Viking, which has severe restrictions on weight and a radiation environment. The pyrotechnic subsystem consists of power conditioning equipment, relay switching control, control logic, and capacitor banks for high pulse discharge.

The pyrotechnic control system derives power and initiating signal from several sources.

1) *Separation events* - Initial charging of the capacitor banks and initiation signal are provided by the spacecraft. After the postseparation battery has been activated, power is then derived from the probe postseparation battery.

2) *Postseparation events* - Power is derived from the probe postseparation battery and initiation signals from the probe data management system.

3) *Preentry battery event* - Power is derived from a 40-volt Hg-Zn battery. This is the only function for this battery, which must maintain the capacitors on charge for about 20 minutes. The initiation signal is derived from the electromechanical (Accutron) timer.

4) *Preentry events* - Power is derived from the probe preentry battery. Initiation signals are provided by the data management system.

1. Power

Except for the entry battery pyro event, all power conditioning required in the pyrotechnic control subsystem is provided by an internal power supply. Outputs are not regulated and have a tolerance of ±10%. The outputs consist of two 40-volt windings completely isolated from each other and from all other windings. Voltages provided for internal use are tabulated.

Capacitor charging	+40
Relay switching	+28
Logic circuitry	+5
Digital interface circuitry	±5

The supply has an output capability of approximately 50 W and a standby power dissipation if 450 mW. Because the supply is essential in the standby condition at all times, except for approximately 5 seconds after each event, the assumed average power requirement is 0.5 W.

2. Relay Assembly

Magnetic latching relays are used for pyro firing functions as well as for safing and arming. This is a deviation from the Viking approach, which uses SCRs for firing. The modification results from the susceptibility of SCRs to the high-radiation environment near Jupiter. The relay selected for this purpose and for estimated weight and size is Potter Bromfield Type HL 4125 (MIL-R-5757). The relays weigh 0.29 kg (0.063 lb) with a volume of 11.12 cm^3. The present configuration assumes one relay for each side of the redundant squib and one for safing and arming in the common lead. This approach requires three relays for each event.

Considerations to be evaluated for this design are the effect of contact bounce on the operation of the squib, possible fusing of contacts (which would leave the capacitor banks connected to the squib circuit), and testing problems. The contact fusing problem could be eliminated by adding another relay for each event and performing safing and arming directly in series with the contacts of the initiator relay. An alternative configuration could use the common-lead relay for firing. However, this would accentuate the effects of contact bounce on the performance reliability. Testing may be a severe problem because the first operation is likely to cause significant damage to relay contacts. A simulated test that measures contact bounce and contact resistance may be sufficient. The effect on the squibs cannot be predicted at this time. The relay manufacturers are reluctant to reduce the specification on contact bounce below 2 msec. Firing time of the squib is approximately 0.4 msec and further study will be required to evaluate this problem. Present Viking design calls for operation of the relay with 8 to 18 volts applied across the coil. A 1600-ohm coil design ensures that sufficient power is available to operate the relay from the low-energy Hg-Zn battery, which initiates the preentry phase of the mission.

3. Capacitor Banks

Each capacitor bank contains six 82 μf capacitors rated at 50 volts. These wet-slug tantalum capacitors are required to deliver 150 mJ in 5 msec into a 1-ohm circuit. Each capacitor bank is required to fire six initiators, one at a time. No two initiators can be

fired by a capacitor bank within a 12-second period. The design is planned to permit charging all capacitor banks from either side of the power supply through charging resistors. Failure of one or several banks will not produce a serious load on the power supply. One possible exception to the resistive cross connection may be the capacitor banks that fire the entry battery pyrotechnics because these are energized by a low-capacity long-life Hg-Zn battery.

The design application of the pyrotechnic subsystem does not depart significantly from state-of-the-art designs, in particular, the Viking design. One aspect that must be given further consideration, because of the nature of the probe mission profile, is the conditioning of the pyrotechnic capacitor banks. Because the various probe designs will have been electrically quiescent for approximately 18 months before separation, the capacitor banks will require reconditioning for approximately 1 hour. A more critical requirement will occur after the quiescent coast period. This represents a significant problem because of the lack of available power. The design approach is to provide a 40-volt Hg-Zn battery that will provide charging current and maintain charge for approximately 20 minutes on two capacitor banks. These capacitor banks will then provide the energy to fire the first entry pyrotechnic. The actuator that initiates the capacity charging and provides the firing control will be mechanically closed contacts in the electrimechanical (Accutron) timer. A 40-volt battery will be used to avoid the need for power conditioning. The only function of this battery is to provide charge current to the capacitor banks, leakage current during the conditioning period, and power to operate the relay initiator logic.

4. Interface

Except for the entry battery pyrotechnic event, all pyrotechnic event control will be provided through the data management subsystem. The control signal will be in the form of parallel digital address, enable, fire, and safe commands. The pyrotechnic subsystem will be enabled by applying power through a power control relay in the power distribution control.

C. REFERENCES

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G-2 C. F. Palandati: *Electron Radiation on Effects on Silver Zinc Cells.* X-716-68-136. GSFC, 1968.

G-3 E. M. Morse: *Eagle-Pincher Silver Zinc Automatically Activated Batteries.* Bulletin No. 101, Eagle-Picher.

G-4 J. A. Sanders: *Remote Activated Batteries.* Memo 0455-71-95, September 9, 1971.

G-5 J. A. Sanders and D.R. Seals: *Test Report on Heat Sterilizable Silver-Fine Batteries.* General Electric Co., 67SD337.

APPENDIX H

DATA HANDLING SUBSYSTEM ANALYSIS AND DEFINITION

E. A. Berkery

June 20, 1972

DATA HANDLING SUBSYSTEM (DHS)

The principal problem in developing a rigorous evaluation of data handling subsystems for a system level study is that the detail requirements which provide the major constraints on the DHS are generally absent. The most significant interfaces (science instruments) lack detail in the sense of synchronization requirements, internal (instrument) processing capability, diagnostic and control requirements. The data that are available, such as science bit rate, measurement duration, intrascience requirements (i.e., simultaneous measurements), are subject to change with changing definition of mission profiles and instrument configurations. Consequently, some generalizations have been made and arbitrary interface descriptions have been assumed where it is necessary to provide a definitive interface. It is understood that the ultimate specifications of the various subsystems could perturb this evaluation; however, the performance required of the DHS is well within the state of the art and no serious obstacle is expected in a detail design of this subsystem.

Sequence of Events - An approximate sequence of events which is applicable to all missions, is shown in Table H-1. During the pre-separation period the probe DHS is controlled by the spacecraft. The primary function during this period will be to decode the serial digital commands from the spacecraft, verify the commands, perform the commands (component turn on, warmup timing, diagnostics), and relay the resulting data to the spacecraft. Since command loop time delay between the ground station and the spacecraft is approximately 1.5 hr, a reasonably automated checkout is desirable. Checkout may be performed at any time before separation; however, it is desirable to limit the number of times the probe is powered up. A pre-separation checkout period of six hours would allow for several probe revision and checkout cycles. The modification to the probe subsystems at this time will consist of switching out components that exhibit catastrophic failure symptoms, assuming a partial data return is still achievable. The Accutron timer will be started before separation at some time $t = E - \tau$. This timer is set for period τ before launch and cannot be reprogrammed in flight. The only function for the Accutron timer is to initiate the entry phase by activating the entry battery. During the immediate ($\approx$6 hr) post-separation sequence, the DHS sequencing logic controls the probe. The ACS subsystem is enabled for the entry orientation maneuver by the DHS. When the maneuver is completed (attitude error less than 3°), the ACS provides a signal that initiates the shutdown of that subsystem by

Table H-1 Nominal DHS Sequence of Events

TIME	FUNCTION	COMMAND SOURCE
S - 6 hr	Energize probe power bus and DHS	S/C DHS
	Start timer	S/C DHS
	Exercise probe functions/checkout	S/C DHS, Probe DHS
S - 1 min	Activate probe battery	S/C DHS
S - 0	Separate	S/C DHS
S + 0		
	Perform spinup, V ACS maneuver	DHS
	Engineering measurements, RF transmission	
S + 6 hr	Initiate coast shutdown sequence	ACS logic
S + 6 + hr	Complete coast shutdown sequence	DHS
E - 85 min	Charge pyrotechnic banks	Coast timer
E - 65 min	Activate descent battery	Coast timer
	Activate DHS timer/sequencer	Bus voltage sensor
E - 45 min	Initiate Pre-entry sequence	DHS
E + 20 sec	Initiate descent sequence (100 g)	G-switch
	Measure/store science/engineering data	DHS
E + 3 min	Resume transmission of measurements and stored data	DHS

the DHS. Obviously, the ACS electronic functions could be included in the DHS; however, it is preferable for overall mission reliability to keep them separate, as will be discussed below. Subsequent to the ACS maneuver, the transmitter is energized and data stored during the post-separation activity is transmitted to the spacecraft. When the transmission is completed, the various subsystems are shut down. The DHS shuts itself down by removing its own power. Delay and signal verification approaches will be used for the shutdown sequence since it constitutes a lock-down mode.

During the coast period, the Accutron timer is the only active electronic component. Power ($\approx$10 μ watts) is supplied by a mercury-zinc battery. The mechanical contacts of the timer provide two events: (1) initiation of capacitor bank charging and (2) firing the pyrotechnics to activate the entry battery. The activation of the entry battery initiates a sequence that enables the DHS. All subsequent events are controlled by the DHS timing and sequencing. During the entry phase, the trajectory uncertainties are removed by sensing deceleration and initiating the descent program.

Configuration Alternatives - The configuration of the data handling subsystem was based on studies of probe requirements for Venus and the outer planets. Consideration was given to a programmable processor controlled system and a hard-wired system. These approaches are exemplified by an Adaptive Control and Data Processing Group (ACDPG) and Control and Data Processing Unit (CDPU). The ACDPG (Figure H-1) consists of a computer and a Processor Interface Unit (PIU) that includes all the functional blocks except the computer. The selected computer is a nonredundant version of the Advanced Onboard Processor (AOP) which is being considered by Martin Marietta for outer planet spacecraft. It employs a plated wire memory and bipolar (non-MOS) LSI circuits. An increase of approximately 12 lb and 4.0 watts over the CDPU version could be traded off against savings in weight and power in attitude control and the instruments by the use of a system like the ACDPG. Since the AOP computer is designed for a redundant configuration and some of the electronics is dedicated to redundancy functions, it may be expected that an additional 10 to 30% decrease in weight and power could be achieved for the computer.

The evaluation of the CDPU (Fig. H-2) involved a rather pragmatic evaluation of mission viability that considered the fluctuating instrument designs with consequent changes in interface requirements, development costs, schedule, and practical reliability

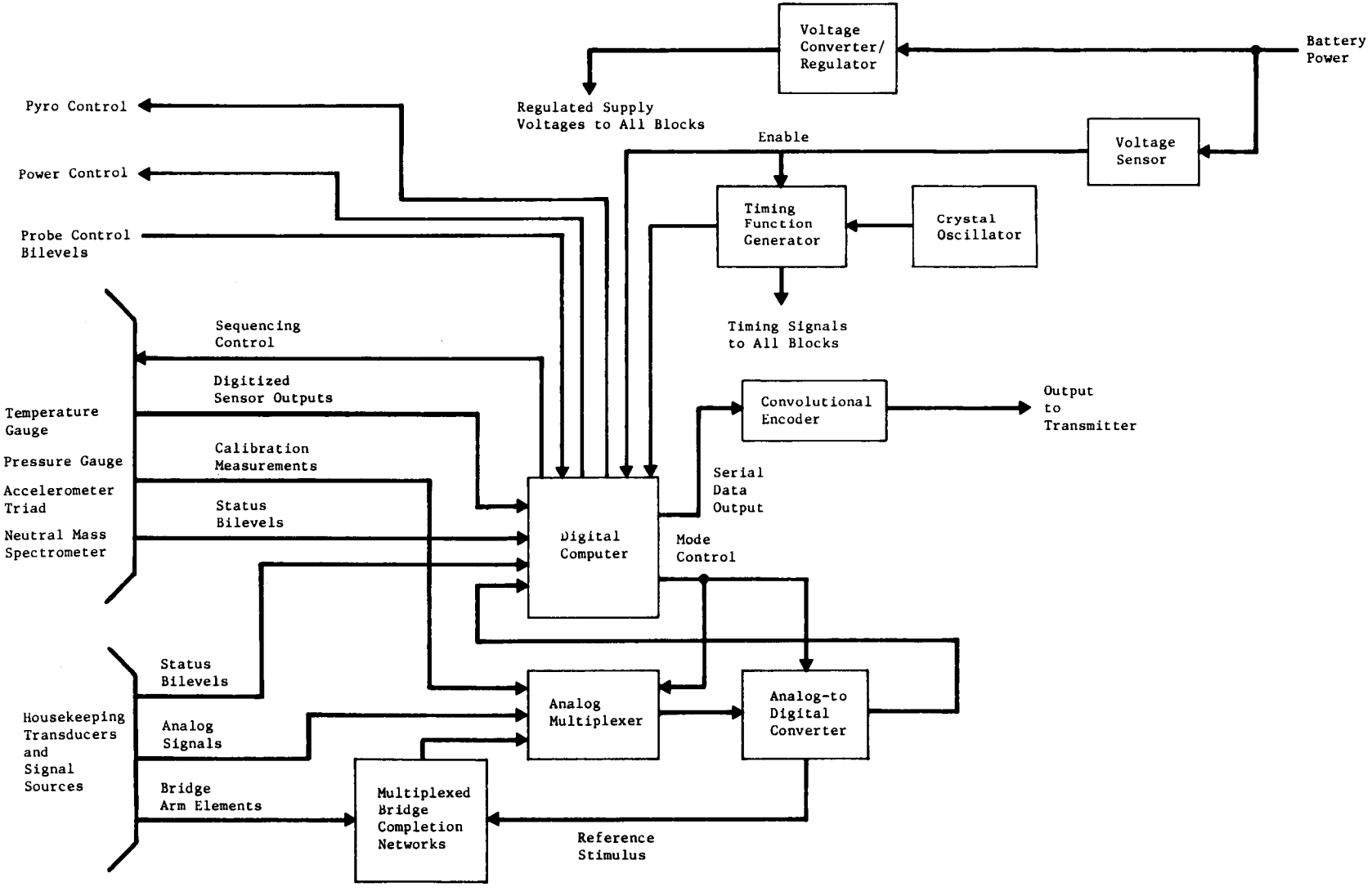

Figure H-1 Data Handling Subsystem, General Purpose Approach

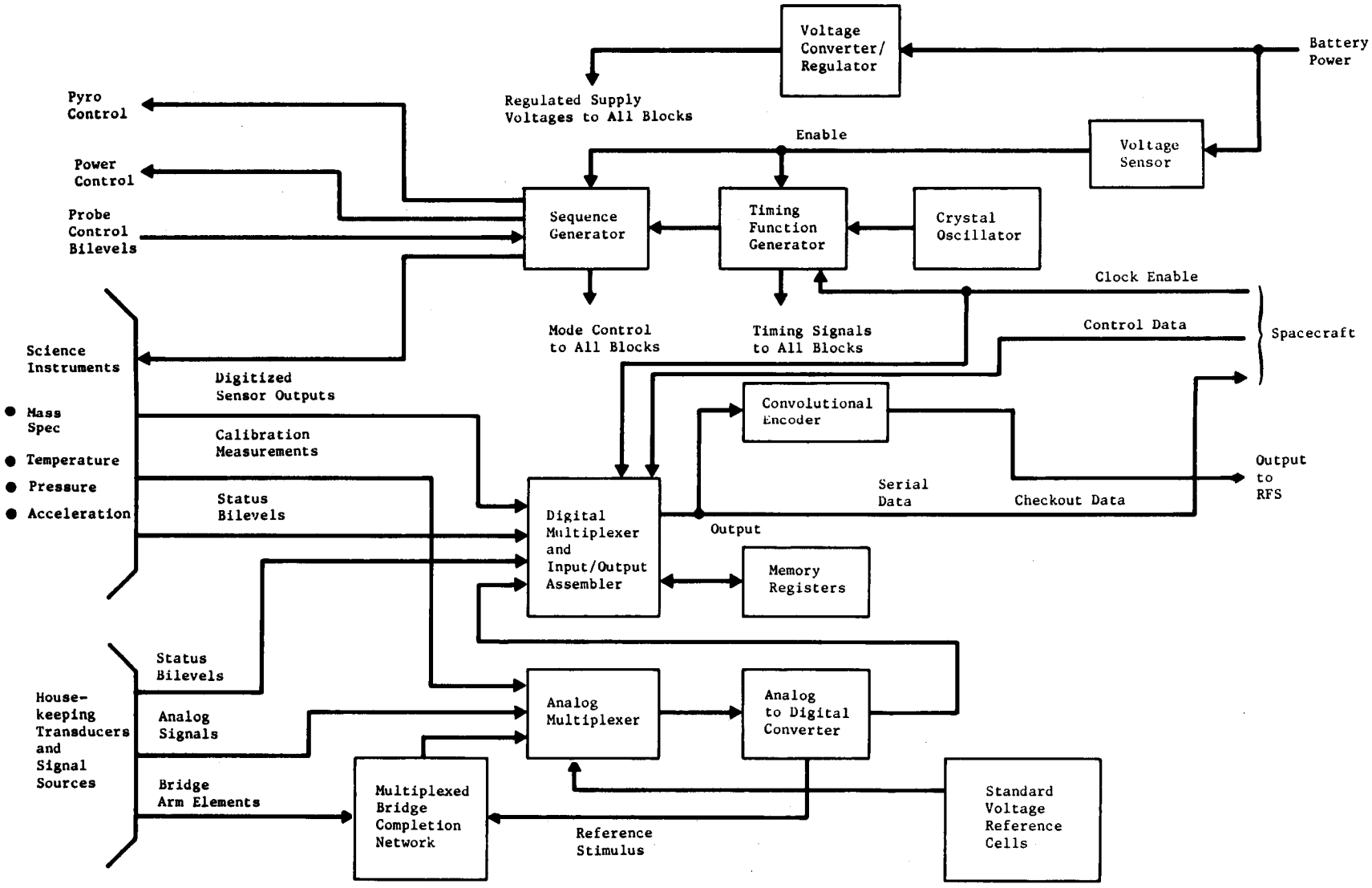

Figure H-2 Data Handling Subsystem Diagram, Special Purpose Approach

aspects. The major functional requirements of the data management subsystem are shown in Table H-2, Except for the entry accelerometer instrument, there are no significant storage requirements. For any specific atmosphere, there is a fixed sequence and format. Consequently, the decision-making capability and processing complexity of the subsystem tend to be minimized. The decision as to the locale of the various functions must consider the fluctuation of the science processing requirements during the development of the instruments as well as the significant differences between instruments. The high radiation, g-stress and long life environment and the value of partial data return provide a basis for a decentralized DHS. The remaining functions, which are necessarily common to all subsystems (i.e., formatting and sequencing), should be well protected from failure by redundancy. A decentralized subsystem should be cost and schedule effective through the development program.

The design of a DHS, which primarily serves to provide formatting, sequencing and encoding, may be implemented from available qualified components, integrated circuits and piece parts. Selection of such devices will be heavily influenced by established reliability and radiation resistance.

Consideration of atmospheric uncertainties indicate a need for adaptive functions in the subsystem that could conceivably optimize the data return. With the present instrument package, the advantages of optimization with respect to the data return and probe design do not appear to be significant. Furthermore, the information available (i.e., temperature and pressure) are not sufficiently well known to make a valid format decision at the required altitudes.

As a result of the above considerations and comparisons the recommended approach is the special purpose CDPU. The alternative configuration may be reconsidered if there is extensive elaboration of the instrument payload or a flexible inflight programmable system is required.

Selected Configuration - The functional block diagram of the special purpose DHS is shown in Figure H-2. The DHS performs only the necessarily centralized functions of timing, sequencing, and formatting. The subsystem is energized twice, by the spacecraft before pre-separation checkout and by the coast timer/bus voltage sensor during the pre-entry period. The probe bus voltage sensor has an additional function in that it provides controls so that

Table H-2 Data Management Functional Requirements

Function	Application	Function Locale	Comments
Timing	Sequencing	DHS	Hardwire/Programmable
	Synchronization	DHS	Sync Bus
Data Storage	Accelerometer	DHS	Blackout Data
	Engineering	DHS	Probe Readiness
Data Processing	Accelerometer	DHS/Inst	Turbulence
	NMS	Inst	A/D
	Pressure	DHS/Inst	A/D
	Temperature	DHS/Inst	A/D
	Engineering	DHS	A/D
Sequencing/ Format	Pre-entry Probe Readiness	DHS	Coast Timer/Battery Initiate
	Data Transmission	DHS	Engineering Data
	Post-Entry Blackout	DHS	G-Switch Initiate
	Probe Readiness	DHS	Engineering/Accelerometer Data
	Data Transmission	DHS	Descent Format

the DHS is disabled until full power is on the bus, and signals are available to ensure that the internal states of the DHS are properly set. Once energized the timer and sequence generator control the probe functions. The DHS receives two additional commands: (1) the accelerometer signals the presence of signif-cant g-level to prevent overloading the science data storage memory with useless pre-entry acceleration data; (2) g-switches provide signals to initiate the descent format.

It is assumed that the science instruments will have ten- or 12-bit buffer storage output to hold the measurements and signal the state of the instrument. Information is shifted from these buffers into the appropriate DHS memory registers. Although this procedure produces some redundancy in the electronics, it facilitates the simultaneous measurements that must be made by the science instruments and will also reduce design schedule interference between probe engineering design and changing science objectives. The bridge completion networks, analog multiplexer and A/D converter, are provided for engineering measurements. Standard voltage cells (chemical cells or zenor diodes) are provided for calibration and measurement purposes. (The difficulty of maintaining a voltage standard for as much as eight years is recognized; however, the probe may be calibrated during pre-separation checkout. This will ensure that probe accuracy is approximately equal to the accuracy of the spacecraft.) The data in the DHS buffer storage is then sequenced into the data stream and convolutionally encoded.

In addition to the science instruments, the DHS controls vehicle pyrotechnics, power, ACS, and RF transmission. Their functions are indicated by the "pyro" and "power" control interfaces. Incoming commands from the accelerometer and g-switches are indicated by the "probe control bilevels."

The physical characteristics were based on estimates of devices required for each function. Included in this estimate were 14-lead flat packs, LSI packages, hybrids, transistors, diodes, resistors, capacitors (small and large tantulum) coils, and transformers. Card surface area was allocated for each device and total surface area calculated. Board thickness of 0.75 cm and a density of 0.93 gm/cm^3 were assumed. These estimates resulted in the following physical characteristics: volume 2320 cm^3, weight 2.13 kg, power, 6.9 W.

The weight of the memory was based on an estimate from Electronic Memories (Division of Electronis Memories and Magnetics Corp). The estimate for a 7 kb bipolar, IC memory (8 kb card) follows: volume/6.5 x 11.4 x 0.64 cm, weight 0.23 kg, power 6 watts. These data have been used as a basic building block for the cost of memory capacity.

The resulting physical and electrical definition of the nominal Jupiter probe DHS and is volume 2575 cm^3, weight 2.59 kg, power 18.9 watts.

Redundancy and Coding - The use of redundancy has not received significant attention in the probe electronics design; however, it is realistic to assume that with the long-life, radiation environment and volatile bipolar IC memory electronics, some efforts will be required in this area. Redundancy techniques may involve the design of the DHS to a greater extent than other systems because of the central control function. While passive (majority vote logic, derating, etc.) redundancy techniques may be applied effectively to many types of circuitry, technologies such as power subsystems require failure sensing circuitry and switching, Inasmuch as the DHS already controls power switching, the failure detection/correction functions may be more effectively and reliably implemented in the DHS subsystem.

Reliability improvement internal to the DHS would primarily use passive approaches particularly in the critical timing and sequencing counters and logic which provide common control functions. The power requirements of the blackout data storage memories would tend to constrain a reliability improvement approach to the use of a parity bit per word; the relatively low capacity buffer memories would use passive techniques.

The data encoding requirements arise because of relay link requirements rather than probe requirements. A noncoherent FSK system and especially a binary system will give poor performance when compared to that attainable according to the Shannon Theory. In order to offset this deficiency error correcting codes are used.

Convolutional codes are easiest to implement and provide the best performance; therefore, only convolutional codes were considered in this study. Either long or short constraint length codes may be used, depending upon the amount of processing, if any, to be

done on the spacecraft. Spacecraft options range from digitally sampling the received signal and recording the data for relay to Earth, to fully detecting and decoding the signal onboard the spacecraft. It was decided, therefore, to assume use of a short constraint length $\kappa = 8$ and rate $\frac{1}{2}$ code to be compatible with any of the available spacecraft signal processing options.

APPENDIX I

MONTE CARLO DEFLECTION DISPERSION ANALYSIS

E. D. Vogt

June 15, 1972

A Monte Carlo computer program is used to compute the dispersions in communication and entry parameters caused by errors and uncertainties at the time of the deflection maneuver. The deflection maneuver itself is defined in detail in subsection IV.D.1 of Volume II of this report. A summary of the Monte Carlo technique is supplied in this appendix.

A. ERROR SOURCES

Two distinct types of errors are identified as causing dispersions from the nominal entry parameters. First, because of errors in the guidance and navigation process prior to the deflection maneuver, there are uncertainties in the spacecraft state at deflection. Secondly, there will be execution errors made by the spacecraft and probe in the implementation of the required maneuver.

1. Guidance and Navigation Uncertainties

Quantitative measures of the uncertainties in the spacecraft state at the deflection point are provided by the control and knowledge covariances* at that point. The control covariance P_c is a 6×6 matrix defined by

$$P_c = E\left[\left(X_{act} - X_{nom}\right)\left(X_{act} - X_{nom}\right)^T\right]$$

where E is the expectation operator and X_{act} is the random variable vector describing the actual state (6 vector of position and velocity) of the spacecraft and X_{nom} is the nominal state of the spacecraft. P_c thus gives a measure of the probabilistic deviation of the actual deflection state from the nominal state.

The generation of the control covariance proceeds as follows. It is assumed that the control errors result solely from errors at the last midcourse correction prior to deflection. A further assumption is made that the last midcourse correction is small enough that the execution errors are dominated by the knowledge errors at the time of the correction. A large *a priori* knowledge covariance is assumed at 25 days prior to the last midcourse maneuver when the tracking for that midcourse is initiated. The *a priori* knowledge covariance is reduced by processing simulated measurements for 25 days to determine the knowledge covariance at the midcourse. This covariance is then simply propagated (processing no measurements) over the last 13 days to generate the control covariance at the deflection point.

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*The control and knowledge covariances referred to in this report correspond to the correlation matrix X of the actual deviation vector and the correlation rating E of the estimated errors in Battin's notation of Reference 1. General analytic details of the formulation of these mathematical tools may be found in this reference.

The knowledge covariance P_k at any point is defined mathematically as:

$$P_k = E\left[\left(X_{est} - X_{act}\right)\left(X_{est} - X_{act}\right)^T\right]$$

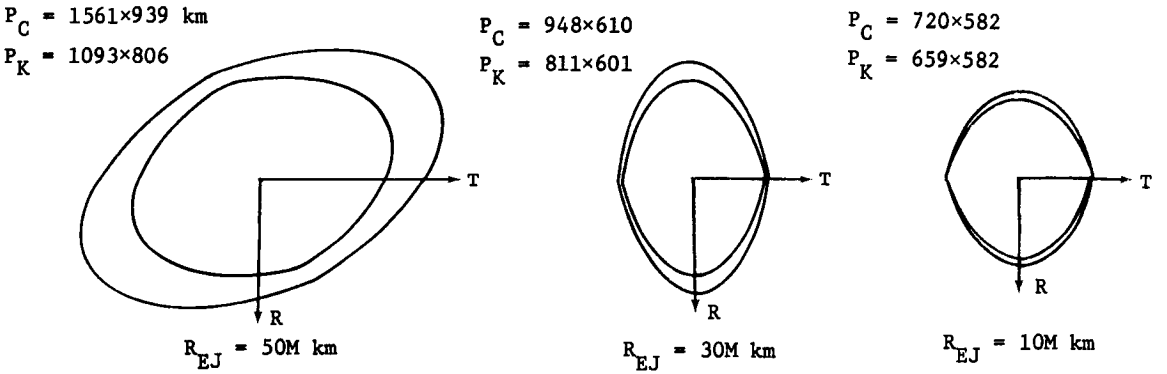
where X_{est} is the random variable representing possible estimated states if X_{act} is the actual state. Thus, P_k provides a quantitative measure of the estimation error to be expected at the time of deflection.

The knowledge covariance is generated similarly to the control covariance. Tracking begins at 38 days prior to deflection and measurement processing continues to one day prior to deflection. The knowledge covariance at that time (the deflection maneuver computation time) is then simply propagated to the nominal deflection time.

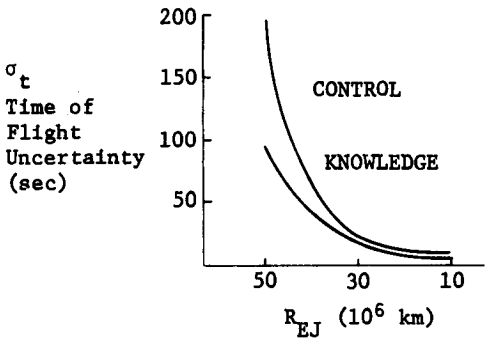
Thus, the knowledge and control uncertainties are really functions of the approach orbit determination (OD) processes. Since the orbit determination process is highly dependent upon the detection of the gravitational effects of Jupiter, the knowledge and control uncertainties decrease as the deflection maneuver is performed nearer Jupiter.

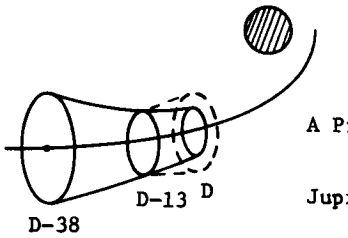
Figure I-1 presents a summary of the control and knowledge covariance computations. The pertinent data used in generating the uncertainties is supplied in Figure I-1C along with a pictorial representation of the process. Deflection radii of 10-, 30-, and 50-million kilometers were studied. These radii correspond to time intervals of approximately 8, 25, and 44 days before encounter. For any of the deflection radii, the tracking was initiated 38 days before deflection tracking through 25 days to generate the midcourse knowledge covariance. That covariance was then propagated forward to deflection to generate the deflection control covariance. Tracking was reinitiated on the midcourse knowledge covariance and carried through to one day prior to deflection. This was then simply propagated over the final day to generate the deflection knowledge covariance.

The dominant part of the deflection covariance matrice is the upper left 3 × 3 partition defining position uncertainties. This may be rotated into the standard RST coordinate system. Then the one sigma uncertainty in the spatial miss or the impact parameter B is defined in the TR plane as indicated in Figure I-1A. The one-sigma uncertainty in the S direction divided by the hyperbolic excess velocity produces the one-sigma time of flight uncertainty given in Figure I-1B.



A. SPATIAL MISS UNCERTAINTIES





B, TIME UNCERTAINTIES

A Priori Covariance σ_R = 5000 km
σ_V = 0.01 m/sec

Jupiter Ephemeris Uncertainty σ_R = 500 km

Doppler Noise: 0.3 mm/sec (1 min count)

Station Location Errors: σ_{RS} = 1.5 m
σ_L = 3.0 m
ρ_L = 0.97

C. GROUNDRULES

Figure I-1 Knowledge and Control Uncertainties at Deflection

The net effect of decreasing the deflection radius on the knowledge and control covariances is evident. Decreasing the deflection radius from 50- to 30-million kilometers reduces the uncertainties by approximately one-third. Decreasing the deflection radius from 30 to 10 million kilometers produces a decrease in uncertainties of approximately one-fourth.

An intuitive feeling for the exact use of knowledge and control covariances may be gained by referring to section B which describes the analytical technique used in the Monte Carlo dispersion analysis program.

2. Execution Errors

The second source of errors analyzed results from execution errors made in implementing the actual maneuvers required. The types of maneuvers encountered in the three modes identified earlier are:

1) Probe deflection maneuver;

2) Spacecraft deflection maneuver;

3) Probe release and/or orientation.

The error models used to analyze each of these maneuvers are described in the following paragraphs.

The purpose of the probe or spacecraft deflection maneuvers is to add a commanded velocity increment $\underline{\Delta v}$ to the current probe or spacecraft state. The actual velocity increment imparted to the body will differ from the commanded value by an amount $\underline{\delta\Delta v}$ that represents the contribution due to execution errors. The execution error model used in this study is defined by four independent error sources.

The first error source is called the proportionality error and is in the direction of the velocity correction, $\underline{\Delta v}$, with magnitude determined by the proportionality factor, k:

$$\underline{\delta\Delta v_K} = k\ \underline{\Delta v}$$

A second error source in the direction of $\underline{\Delta v}$ but independent of its magnitude, is the resolution error, s, that corresponds to a thrust tailoff error from the thrusters:

$$\underline{\delta \Delta v}_s = \frac{s}{\Delta v} \underline{\Delta v}$$

The other error sources are pointing direction errors. The first of these is a pointing error angle, α, measured in a plane parallel to the ecliptic plane (for Jupiter missions, approximately the orbital plane), and along a vector orthogonal to the velocity correction vector, $\underline{\Delta v}$. If $\underline{i}$, $\underline{j}$, $\underline{k}$ form the unit triad in the ecliptic system, then for small angles, α, the velocity error caused by the in-plane pointing error is given by

$$\underline{\delta \Delta v}_\alpha = c \, \Delta v \, \alpha \left[\Delta v_y \, \underline{i} - \Delta v_x \, \underline{j} \right]$$

where $\underline{\Delta v} = \Delta v_x \, \underline{i} + \Delta v_y \, \underline{j} + \Delta v_z \, \underline{k}$ and $c = \left(\Delta v_x^{\,2} + \Delta v_y^{\,2} \right)^{-1/2}$. The second pointing error, called the out-of-plane error defines the velocity error that is orthogonal to both $\underline{\delta \Delta v}_\alpha$ and the velocity increment vector, $\underline{\Delta v}$. Again, for small angles, β, the velocity error resulting from this pointing error, referenced to the ecliptic system, is given by

$$\underline{\delta \Delta v}_\beta = \beta c \left[\Delta v_x \, \Delta v_z \, \underline{i} + \Delta v_y \, \Delta v_z \, \underline{j} - \frac{1}{C^2} \, \underline{k} \right]$$

Then the total execution error resulting from a proportionality error, k, resolution error, s, and pointing errors, α and β, is given by the sum of these errors

$$\underline{\delta \Delta v} = \underline{\delta \Delta v}_k + \underline{\delta \Delta v}_s + \underline{\delta \Delta v}_\alpha + \underline{\delta \Delta v}_\beta$$

The mathematical model used to describe velocity increment errors is the same for either spacecraft or probe. The individual magnitudes of the execution error sources, k, s, α, and β, may be varied, however, for individual characteristics of the probe or spacecraft. In general, the Pioneer pointing accuracy is 5% of the angle rotated off Earth lock, the TOPS error is considered to be 1 degree (3σ).

The probe release and/or orientation error is essentially involved with simply aligning the probe axis for its zero degree relative angle of attack at entry. This corresponds to the maneuver by which the probe is released from the spacecraft in the Mode 3/ Deflect Spacecraft sequence or to the probe self-reorientation maneuver in the Mode 1/Deflect Probe scheme. The current mathematical model for this type of maneuver is based on a single pointing error referenced to the desired direction.

Let $\underline{u}_D$ denote the desired direction for the probe axis. Define

$$\underline{v}_1 = \frac{\underline{r} \times \underline{u}_A}{|\underline{r} \times \underline{u}_A|}$$

$$\underline{v}_2 = \underline{u}_A \times \underline{v}_1$$

Then $\underline{v}_1$ and $\underline{v}_2$ are unit vectors in the plane normal to the desired direction $\underline{u}_A$. An arbitrary unit vector in that plane may then be written.

$$\underline{x} = \underline{v}_1 \cos \theta + \underline{v}_2 \sin \theta$$

where θ is a random variable chosen from a uniform distribution over the interval $(0, 2\pi)$. If the orientation pointing error is to be of magnitude δ, then the actual pointing direction resulting from the error is given by

$$\underline{u}_A = \underline{u}_D \cos \delta + \underline{x} \sin \delta$$

B. ANALYTICAL TECHNIQUE

A Monte Carlo technique is used to convert the errors associated with the deflection maneuver into dispersions in the critical mission parameters. The Monte Carlo procedure will be defined in detail for the Mode 1/Deflect Probe deflection scheme. The modifications for the Mode 2/Shared Deflection and Mode 3/Deflect Spacecraft schemes are then easily explained.

The Monte Carlo technique used in this study consists of generating a large number of sample probe and spacecraft trajectories consistent with assumed statistics of the knowledge and control uncertainties and execution errors. These trajectories are then propagated to certain mission time points (probe acquisition by spacecraft, entry, and selected intermediate points), and the critical mission parameters are evaluated. Because each sample spacecraft and probe trajectory will differ from the nominal (errorless) ones, the critical parameters will also differ. The data in dispersions in critical mission parameters are then analyzed by empirical formulas, assuming normal distributions

to establish mean and three sigma deviations in each critical parameter for each selected time point. The computational flow, outlined in Figure I-2, may be broken up into three main components that are discussed in detail.

1. Preliminary Computations

The preliminary computations generally comprise the determination of the nominal trajectories and preparation for the selection of the perturbed trajectories. The nominal deflection maneuver is first computed, which for the given hyperbolic excess velocity (equivalently the given launch date/arrival date) and desired deflection radius satisfies the desired entry conditions and communication geometry. The knowledge and control covariances, P_k and P_c, are then computed from an orbit determination program in which the procedure described in section A is used. Finally, the execution error uncertainties, σ_k, σ_s, σ_α, σ_β, σ_δ, are selected on the basis of the spacecraft used, the nominal geometry involved (such as the rotation off Earth lock required to implement the maneuver), and the magnitude of errors requiring analysis.

2. The Sampling Procedure

The bulk of the dispersion analysis is concerned with the generation of the statistically consistent ensemble of spacecraft-probe trajectory samples. For each sample, the first problem (listed in Figure I-2) is to generate reasonable deviation vectors, δX_k and δX_c, from the knowledge and control covariances, P_k and P_c. This sampling is done as follows.

Let P represent P_k or P_c. Then, since P is positive definite, it may be diagonalized.

$$P = T^T D T$$

where $D = \text{diag}\,(d_1^2, d_2^2, \ldots, d_6^2)$, T is the orthonormal matrix of the eigenvectors of P, and the superscript T denotes the matrix transpose operation. The elements of D are written as squares to indicate they are necessarily positive numbers.

I. PRELIMINARY COMPUTATIONS

A. Read in nominal spacecraft deflection state X_{nom}
desired entry angle, γ, and lead angle, λ,
knowledge and control covariance matrices, P_k and P_c,
execution error model uncertainties, σ_k, σ_s, σ_α, σ_β, σ_δ.

B. Compute nominal deflection maneuver and parameters

II. SAMPLING PROCEDURE

Generate large number ($N \geq 100$) of sample off-nominal cases.
For each case --

A. Sample knowledge and control covariances to obtain the deviation vectors, δX_k and δX_c.

B. Form the actual and estimated spacecraft states

$$X_{act} = X_{nom} + \delta X_c$$

$$X_{est} = X_{act} + \delta X_k$$

C. Compute the commanded velocity increment, Δv_c, based on the estimated state, X_{est}, and the desired γ and λ.

D. Sample the execution errors, generate the resulting error in velocity increment, Δv. Compute the post-deflection probe state as

$$Y_{act} = X_{act} + \begin{bmatrix} -\Delta\bar{v}_c \\ \bar{0} + \delta\bar{\Delta v} \end{bmatrix}$$

$$Y_{est} = Y_{act} + \delta X_k + u$$

E. Compute the desired orientation of the probe at entry, $\underline{u}_\alpha$, using Y_{est}. Generate a sample orientation error and compute the corresponding actual probe orientation, $\underline{u}_A$.

F. Propagate the actual probe and spacecraft to probe entry using conic formula. Store the dispersions in critical mission parameters at each timepoint.

III. STATISTICAL ANALYSIS OF DISPERSION DATA

Using the dispersion data generated for each sample case, compute the mean and standard deviaiton for each critical mission parameter for each selected timepoint.

Figure I-2 Computational Flow Chart of Monte Carlo Analysis Program

T defines a transformation from the original Cartesian coordinate system to a new system in which the covariance matrix is uncorrelated, thereby allowing the individual components to be sampled independently. A vector random variable from a distribution of mean zero and covariance, D, is given by

$$Z = \left(e_1 d_1, e_2 d_2, \ldots , e_6 d_6\right)^T$$

where each e_i is a scalar random variable sampled from a normal distribution of mean zero and standard deviation unity. The e_i are computed from the formula

$$e_i = \sqrt{-2 \ln \alpha_i} \cos\left(2\pi \beta_i\right)$$

where α_i and β_i are random numbers generated from a uniform distribution over the interval (0, 1). The correlated deviation vector in the original Cartesian coordinate system may now be computed using the transformation matrix, T, as

$$\delta X = T \delta Z$$

Therefore, for each sample case, the knowledge and control covariances may be sampled as above to produce knowledge and control state deviation vectors, δX_k and δX_c. The "actual" spacecraft state for the sample is given by

$$X_{act} = X_{nom} + \delta X_c .$$

The "estimated" state of the spacecraft at deflection is given by

$$X_{est} = X_{act} + \delta X_k .$$

Furthermore, at the end of a large number of samples ($N \geq 100$), the ensemble of deviations, δX_c and δX_k, should obey the empirical formulas

$$E\left(\delta X_c \, \delta X_c^T\right) \rightarrow P_c \text{ as } N \rightarrow \infty$$

$$E\left(\delta X_k \, \delta X_k^T\right) \rightarrow P_k \text{ as } N \rightarrow \infty .$$

These approximations are checked at the end of the sampling process to ensure that a statistically consistent set of data has been generated.

Having obtained the estimated state of the spacecraft for a sample, the next task is to determine the commanded velocity increment, Δv_c, to be added to the probe at deflection. The vector, Δv_c, is computed as a function of the estimated spacecraft state at deflection, the desired probe flight path angle at entry, γ_c, and the desired lead angle, λ_c. The lead angle is the angle between the radius vector to the probe at entry and the radius vector to the spacecraft at the time of entry. The lead angle is negative when the probe leads the spacecraft. The deflection velocity is determined by iterating on the value of $\Delta\theta$, the true anomaly increment of the probe in going from deflection to entry. The true anomaly of the probe at entry, f_{PE}, can be expressed as:

$$f_{PE} = f\ \gamma_c, R_{EJ}, \Delta\theta, R_A$$

where R_{EJ} is the radius of the bus at deflection and R_A is the radius of the atmosphere. f_{PE}, R_{EJ}, $\Delta\theta$, R_A are used to compute the time of flight, T, from deflection to probe entry using the universal form of Kepler's equation as presented in Reference 1. The spacecraft state is then propagated forward for time T, again using the universal form of Kepler's equation, and the angle, λ, is computed from the state of the spacecraft and the state of the probe at time T. The angle, λ, is compared with the desired λ_c and the $\Delta\theta$ which causes λ to be within 0.01 degrees of λ_c, is found. Since the orbital elements of the probe are known, the required deflection velocity vector may be calculated. The commanded deflection velocity is in the spacecraft plane of motion.

The deviations in the implemented deflection velocity from the commanded are generated using the model described in subsection A2. This model assumes the implementation error is given by three sources: proportionality error, K; resolution error, S; and pointing angle errors, α, β. These errors are assumed uncorrelated and normally distributed. The standard deviation of each error σ_K, σ_S, σ_α, σ_β is input to the program. The error used in each Monte Carlo sample is generated by

$$K, S, \alpha, \beta = e_1\sigma_K, e_2\sigma_S, e_3\sigma_\alpha, e_4\sigma_\beta$$

where each e_i is a scalar random variable sampled from a normal distribution of mean zero and standard deviation unity. The execution error, $\delta\Delta v$, is then the sum of these errors.

The actual state of the probe at deflection is then the actual position vector of the probe and the sum of velocity of the spacecraft and the actual deflection, Δv, given to the probe.

$$Y_{act} = X_{act} + \begin{bmatrix} 0 \\ \Delta v_c + \delta\Delta v \end{bmatrix}$$

Now that the actual states of the probe and spacecraft are known, the time histories of these two point masses may be computed using conic models.

The attitude of the probe is a crucial parameter, however, as this determines such mission critical parameters as angle of attack at entry and probe aspect angle. Using the nominal trajectory, the desired probe attitude is computed, $\underline{u}_\alpha$. A pointing error caused by imperfections in the attitude control system is computed in a similar statistical fashion as described above. Once the "actual" probe axis is computed, it is assumed to hold that orientation throughout the mission. No errors are added to the spacecraft axis since it is assumed that the spacecraft can hold the Earth lock with essentially no error.

For each sample probe and space trajectory and probe attitude, the critical entry and communication parameters may be computed as functions of time. The resulting collection of data must then be analyzed by the techniques described in the next subsection.

3. Statistical Analysis of Dispersion Data

The empirical computation of the standard deviations of scalar parameters such as entry angle, lead angle, or lead time may be computed in the following way. Let α_i be the value of any such parameter for the i^{th} case. Suppose that there are N samples to be analyzed. Then the mean and standard deviation of the distribution of α are given by

$$\bar{\alpha} = \frac{1}{N} \sum_{i=1}^{N} \alpha_i$$

$$\sigma_\alpha^2 = \left[\sum_{i=1}^{N} \frac{\alpha_i^2}{N} \right] - \frac{\bar{\alpha}^2}{N}$$

These formulas must be extended for vector quantities. The probe entry site dispersions are given in terms of the two vectors of latitude and longitude (LAT, LON). The spacecraft-probe look direction is conveniently described in terms of the two vectors of cone angle and clock angle (CA, CLA) referenced to Earth and Canopus. Equivalently, these dispersions may be defined in terms of cone angle and cross-cone angle (CA, CCA).

Let Z_i represent the vector describing the actual values achieved for a vector quantity on the i^{th} sample. Then, the vector of mean values and the covariance matrix describing uncertainties and correlations of the vector are given by the formulas

$$\bar{Z} = \frac{1}{N} \sum_{i=1}^{N} Z_i$$

$$P_z = E(ZZ^T) - E(Z)E(Z)^T$$

$$= \frac{1}{N} \left[\sum_{i=1}^{N} ZZ^T \right] - \frac{\bar{Z}\,\bar{Z}^T}{N}$$

These formulas are used to compute the covariance matrices of the critical mission vector quantities as well as to reconstruct the original knowledge and control covariances from the deviation vectors generated.

For the entry stie dispersions (LON, LAT) and the spacecraft-probe look directions (CA, CLA) or (CA, CCA), the 2 × 2 covariances are further analyzed. Let any such covariance matrix be denoted P. Then since P is positive definite it may be diagonalized to produce

$$P = TDT^T = T \begin{bmatrix} \lambda_A & 0 \\ 0 & \lambda_B \end{bmatrix} T^T$$

Where λ_A and λ_B are the (positive) eigenvalues of the covariance matrix P, and T is the orthonormal matrix of the eigenvectors of P. Let

$$T = \begin{bmatrix} t_A \\ - \\ t_B \end{bmatrix}$$

Then t_A is the unit eigenvector associated with the eigenvalue, λ_A. Then the angle between the vector, t_A, and the u_x unit vector (longitude direction for (LON, LAT), cone angle direction for (CA, CLA) or (CA, CCA) is defined by

$$\theta = \cos^{-1}\left(t_A \cdot u_x\right) \quad 0 \leq \theta \leq \pi$$

The uncertainty ellipse may now be easily constructed: λ_A represents one semiaxis; λ_B the other.

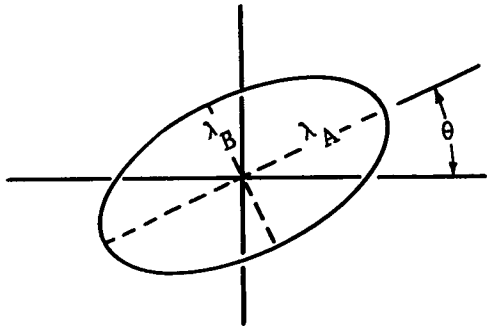


Figure I-3 Two-Dimensional Uncertainty Ellipse

4. Procedures for Alternative Deflection Modes

The procedure for Mode 1/Deflect Probe has been described in detail. A comparison of the procedures for the Mode 2/Shared Deflection and Mode 3/Deflect Spacecraft is provided in Figure IV-3 of Volume II of this report.

For each sample in each mode, the initial task is to determine the control and knowledge deviations, δX_c and δX_k, by sampling the control and knowledge covariances. The actual state of the spacecraft is then defined by $X_{act} = X_{nom} + \delta X_c$; the estimated state of the spacecraft is $X_{est} = X_{act} + \delta X_k$, where X_{nom} is the nominal spacecraft deflection state.

In Mode 1/Deflect Probe the estimated state, X_{est}, is used to determine the commanded probe deflection, Δv. This velocity increment is then degraded by an execution error, $\delta\Delta v$, determined by sampling from possible execution errors. The probe axis orientation throughout the mission is computed as the nominal orientation corrupted by an orientation pointing error, δ. The deflection states for the probe and spacecraft are then propagated to a series of time points at which the sample deviations are recorded. These dispersions are then analyzed to yield mean and standard deviation values.

In the study of the Mode 1/Deflect Probe deflection scheme, it was discovered that the knowledge and control uncertainties did not significantly affect the critical mission parameters. Therefore, to simplify the Mode 2/Shared Deflection analysis, it was assumed that the knowledge and control uncertainties were zero so that the spacecraft correction, Δv, could be precomputed and simply read in. At probe deflection, the probe is commanded to be aligned in the direction of both the Δv and zero angle of attack orientation. Because of the in-plane and out-of-plane pointing errors, the correct direction is not achieved. The incorrect orientation is then used for both the Δv addition and the probe longitudinal axis. Following the probe deflection, the spacecraft correction is implemented with the execution error model described in subsection A2. The resulting sample deviations are then collected and analyzed to determine the mean and standard deviations.

For Mode 3/Deflect Spacecraft deflection analysis, the knowledge and control uncertainties are again considered. The probe is oriented at release using the input orientation pointing error, δ, and keeps that attitude throughout the mission. The estimated state of the spacecraft, X_{est}, is used to compute the deflection, Δv. Spacecraft execution errors are then sampled to determine the error, $\delta\Delta v$. The erroneous velocity increment is then added to the spacecraft and the spacecraft is then propagated to the selected time points. The critical mission parameter deviations are then recorded and analyzed to determine the important statistical data.

C. REFERENCE

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APPENDIX J

MULTILAYER INSULATION CONDUCTIVITY EVALUATION

C. Webb

June 15, 1972

To evaluate insulation performance accurately, two applicable data sources on multilayer insulation were obtained. The first source represented laboratory guarded hot plate test data (Ref 1), the second source represented thermal conductivity test data from an actual hardware mockup where fiberglass standoffs penetrated the insulation blanket and seams and joints were present (Ref 2). Figure J-1 presents a comparison between these two sets of data. In addition, an analytical curve fit is shown for each set where the expression representing the thermal conductivity considered both the linear conduction and the radiation associated with multilayer insulation. The expression, therefore, includes the influence of the mean insulation temperature and, in addition, the nonlinear influence of the actual boundary temperatures. The expression used for the multilayer insulation follows:

$$k = aT_M + b\left(T_H^2 + T_C^2\right)\left(T_H + T_C\right) \qquad [J-1]$$

where,

k = effective thermal conductivity

a & b = influence coefficients

T_M = insulation mean temperature

T_H = hot boundary temperature

T_C = cold boundary temperature

and

$$Q_{leak} = \frac{kA}{t}\left(T_H - T_C\right) \qquad [J-2]$$

where

Q_{leak} = Blanket heat leak

A = insulation surface area

t = insulation thickness.

The importance of this expression is that it more precisely determines the thermal conductivity as a function of boundary temperature and thus insulation thickness variations.

For outer planet entry probe system thermal analyses, the Skylab conductivity data was selected to determine the baseline influence coefficients of Equation [J-1] and thus the multilayer insulation performance.

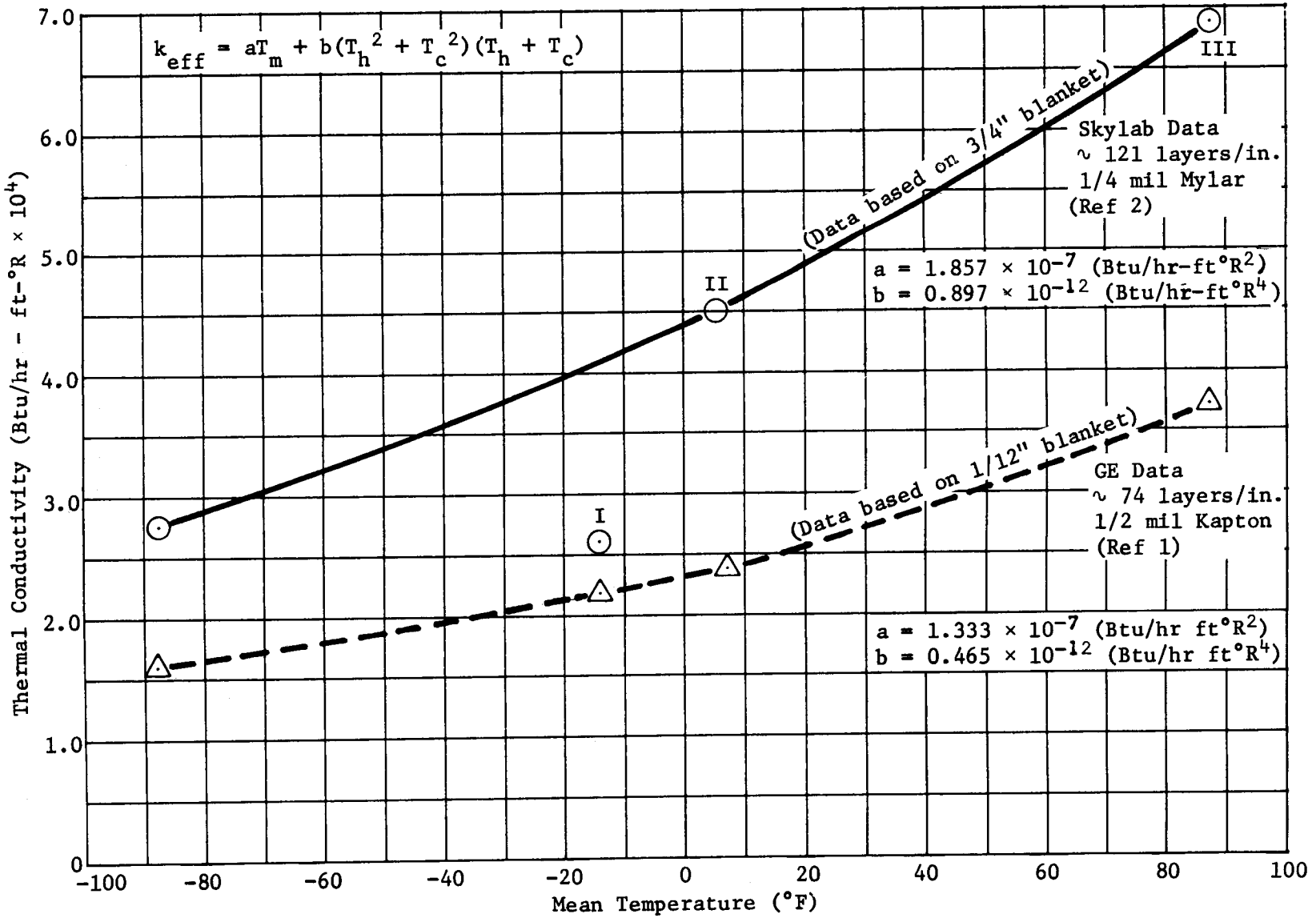

Figure J-1 Multilayer Insulation Thermal Conductivity

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APPENDIX K

NH_3 AND H_2O CLOUD MODELS FOR THE OUTER PLANETS

W. S. Cook

May 1, 1972

Report No. D-72-48740-005

NH_3 - H_2O CLOUD MODELS

FOR

THE OUTER PLANETS

Report Date: May 1972

Note: This Report is issued under
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FOREWORD

This report was prepared by the Denver Division of the Martin Marietta Corporation, Systems Analysis Department. The Task Authorization was 48740.

ABSTRACT

Ammonia and water cloud structures are calculated for the outer planets. This report presents the theory, the computational procedures, and the results. The results are based on the atmospheric models provided in References 3, 4, and 5.

TABLE OF CONTENTS

I. INTRODUCTION

Radio attenuation in the atmospheres of the outer planets is dependent upon cloud structures. John Lewis (Ref. 1) has published the theory necessary for predicting ammonia-water clouds; and with the help of the empirical formulas provided by C. Haundenschild (Ref. 2) the cloud structures for the outer planets were predicted.

II. THEORY

From the first law of thermodynamics, conservation of energy for a molar parcel of atmosphere undergoing an adiabatic expansion, gives

$$\overline{C}_v\, dT + Pdv + \sum_i \lambda_i\, dX_i = 0 \qquad \text{Eq. 1}$$

where $\overline{C}_v$ is the mean molar specific heat at constant volum e, dT is a differential change in the absolute temperature, P is the total pressure, dv is the differential change in the molar volume, λ_i is the molar heat of condensation of the i^{th} gas component, and dX_i is the differential change in the number of moles of condensible gas present in the atmosphere. The equation of state of the bulk gas is

$$Pv = RT \qquad \text{Eq. 2}$$

where R is the universal gas constant thus

$$Pdv = RdT - vdP \qquad \text{Eq. 3}$$

substituting Eq. 3 into Eq. 1

$$\overline{C}pdT - vdp + \sum_i \lambda_i dX_i = 0 \qquad \text{Eq. 4}$$

where $\overline{C}p = \overline{C}_v + R$.

The variation of the vapor pressure of any condensate j with temperature is given by the Clausius-Clapeyron equation for evaporation or sublimation

$$dp_j = \frac{\lambda_j P_j}{RT^2}\, dT \qquad \text{Eq. 5}$$

The equation of state for the j^{th} the component of the condensable gas is

$$P_j V = X_j RT \qquad \text{Eq. 6}$$

Equation 5 is for the case where the molar volume of the solid or liquid is neglected with respect to the molar volume of a gas; therefore, from equation 5 and 6 holding the molar volume constant

$$dp_j = \frac{\lambda_j P_j}{RT^2}\,dT = \frac{\chi_j \cdot RdT}{V} + \frac{RT}{V}\,d\chi_j \qquad \text{Eq. 7}$$

and solving for $d\chi_j$

$$d\chi_j = \chi_j\left(\frac{\lambda_j}{RT^2} - \frac{1}{T}\right)dT \qquad \text{Eq. 8}$$

The equation for hydrostatic equilibrium is

$$\boxed{dp = -\frac{\overline{\mu} GP}{RT}\,dZ} \qquad \text{Eq. 9}$$

where $\overline{\mu}$ is the molecular weight, G is the gravitational acceleration, and dZ is a vertical height increment.

Substituting Eq's 8 and 9 into Eq. 4 for the case in which only a single condensate is condensing

$$\overline{C}p\,dT + \overline{\mu}G\,dZ + \left[\lambda_j \chi_j\left(\frac{\lambda_j}{RT^2} - \frac{1}{T}\right)\right]dT = 0 \qquad \text{Eq. 10}$$

thus the wet adiabatic temperature lapse rate is

$$\frac{\partial T}{\partial Z} = -\frac{\overline{\mu}G}{\overline{C}p + \lambda_j \chi_j\left[\frac{\lambda_j}{RT^2} - \frac{1}{T}\right]} \qquad \text{Eq. 11}$$

We now need to modify Eq. 11 for a system of two condensates, water and ammonia. Let us imagine an isothermal process in which $d\chi_B$ moles of solution with constant molar ammonia concentration are evaporated. Then

$$d\chi_A = c\,d\chi_B \qquad \text{Eq. 12}$$

where $d\chi_A$ is the change in the number of moles of ammonia in solution, and C is the molar concentration of ammonia present in solution, then

$$d\chi_W = (1 - C)\,d\chi_B \qquad \text{Eq. 13}$$

where $d\chi_W$ is the change in the number of moles of water in solution. Using Eq. 6 for the isothermal case

$$dP_W = RT\,d\chi_W = (1 - C)\,dP_B \qquad \text{Eq. 14}$$

From equation 5 considering only the condensation of H_2O

$$dP_W = P_W \frac{\lambda_W}{RT^2} dT \qquad \text{Eq. 15}$$

Since actually we are evaporating water plus ammonia, the latent heat for the bulk solution should be employed;

$$\lambda_B = C\lambda_A + (1 - C)\ \lambda_W \qquad \text{Eq. 16}$$

and equation 15 can be rewritten for the bulk solution

$$dP_B = \frac{P_W}{(1-C)} \frac{\lambda_B}{RT^2}\ dT \qquad \text{Eq. 17}$$

From Eq. 6 we proceed as in Eq. 7

$$\frac{P_W}{(1-C)} \frac{\lambda_B}{RT^2}\ dT = \frac{\chi_B\ RdT}{V} + \frac{RT}{V}\ d\chi_B \qquad \text{Eq. 18}$$

thus

$$d\chi_B = \chi_W \left(\frac{\lambda_B}{(1-C)\ RT^2} - \frac{\chi_B}{\chi_W T} \right) dT \qquad \text{Eq. 19}$$

We then combine Eq.'s 9 and 19 to get

$$\overline{C}_p\ dT + \overline{\mu} G dZ + \lambda_B\ \chi_W \left[\frac{\lambda_B}{(1-C)\ RT^2} - \frac{\chi_B}{\chi_W T} \right] dT = 0 \qquad \text{Eq. 20}$$

The wet adiabatic lapse rate for an ammonia-water systems

$$\frac{\partial T}{\partial Z} = \frac{-\overline{\mu}\ G}{\overline{C}p + \lambda_B\ \chi_W \left[\frac{\lambda_B}{(1-C)RT^2} - \frac{\chi_B}{\chi_W T} \right]} \qquad \text{Eq. 21}$$

Equation 21 was derived under the assumption that water was the prime condensate and some ammonia was condensing out at the same time. For the region of Jupiter's atmosphere where ammonia clouds are forming then ammonia is the prime condensate. Equation 11 must then be modified in a similar way as was done when water was the prime condensate; the resulting lapse rate is

$$\frac{\partial T}{\partial Z} = - \frac{\overline{\mu}\ G}{\overline{C}p + \lambda_B \chi_A \left[\frac{\lambda_B}{C\ RT^2} - \frac{\chi_B}{\chi_A T} \right]} \qquad \text{Eq. 22}$$

C. Haudenschild (Ref. 2) has formulated empirical analytic equations for predicting the partial pressures of ammonia and water for the various phases. These equations are presented in Table I and the phase boundaries are graphically presented in Figure 1.

TABLE I. ANALYTIC EXPRESSIONS FOR THE HN_3 - H_2O SYSTEM

SYMBOL	UNITS	DEFINITION	SYMBOL	UNITS	DEFINITION
T	K^o	Temperature	P_2	Torr	H_2O partial vapor pressure
C	$0.0<C<1.0$	Molar Concentration of NH_3 in solution.	P_3	Torr	NH_3 partial vapor pressure
			log		logarithm base 10

Region	Equation	
Solid H_2O	$\log P_2 = 10.447 - 267.01/T$	Eq. 1
Solid NH_3	$\log P_3 = 10.312 - 1691.77/T$	Eq. 2
$(NH_3)_2 H_2O$	$2/3 \log P_3 + 1/3 \log P_2 = 9.777 - 2051.185/T$	Eq. 3
$NH_3 H_2O$	$1/2 \log P_3 + 1/2 \log P_2 = 9.790 - 2219.28/T$	Eq. 4
Solution	$\log P_2 = \log (1-C) + 9.488 \cdot 1.743C^2 \left[\frac{2406.2 + 878.192C^2}{T}\right]$	Eq. 5
	$\log P_3 = \log C + 9.906 + 1.743(C^2-2C) - \left[\frac{2149.65 + 878.192\ (C^2-2C)}{T}\right]$	Eq. 6

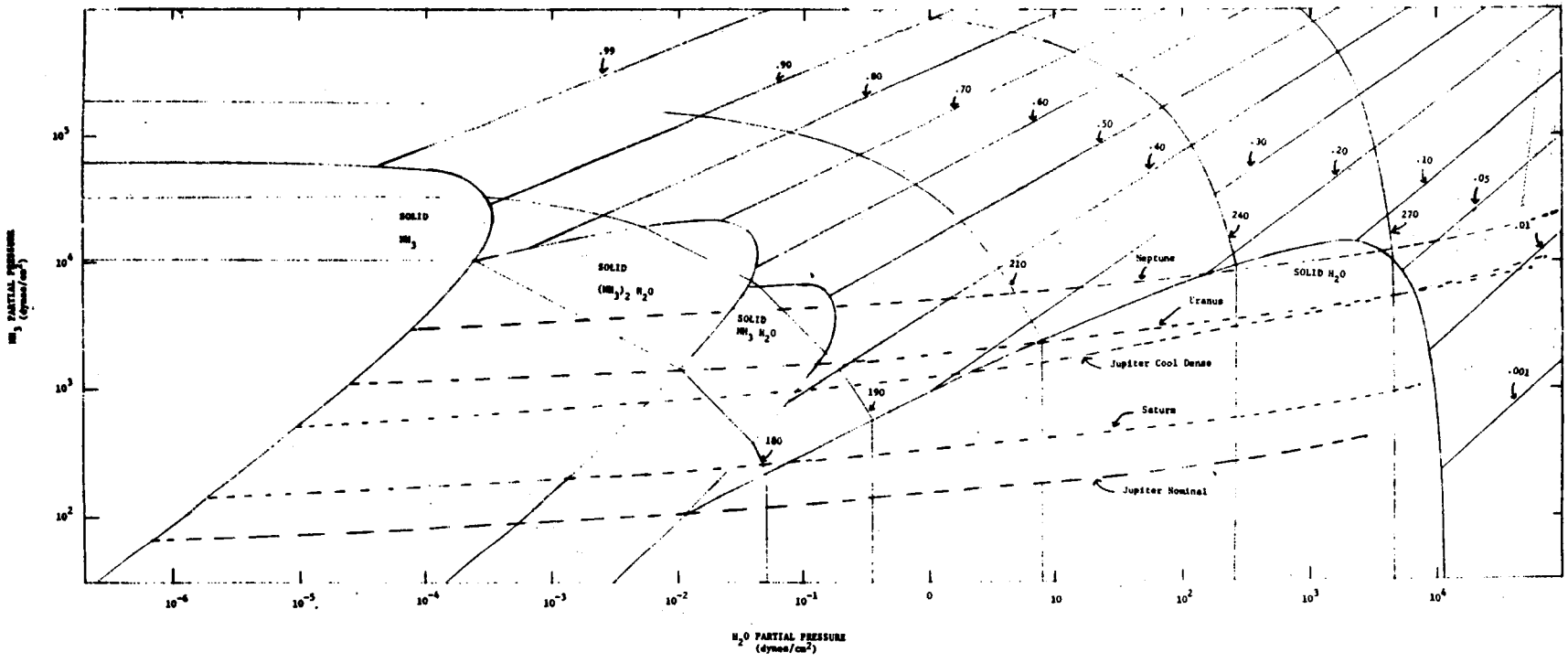


Figure 1. Phase diagram of the NH_3 - H_2O system. The scalloped line running from far left to bottom right is the freezing point line of aqueons NH_3 solutions. The family of diagonal straight lines are lines of constant ammonia concentration in solution. The family of curves intersecting the constant concentration lines are curves of constant temperature. The dashed lines are cloud composition tracks for the different model atmospheres.

III. COMPUTATIONAL PROCEDURES

Given the formulas found in Table I and Eqs. 9, 21, and 22, along with the parameters presented in Table II and Figures 2 and 3, the cloud structures for the outer planets were determined. The computational procedure is as follows:

1) Specify a reference pressure and temperature deep within the troposphere, below the water-ammonia clouds. The reference pressures and temperatures were provided by NASA (Ref.'s 3, 4, and 5) and are included in Table II.

2) Beginning with the reference pressure and temperature, the temperature and pressure are calculated in one Km altitude increments in the positive altitude direction; and after each increment a check is made to see if condensation has occurred. At the base of the lowest-lying solution clouds, the vapor pressures of NH_3 and H_2O are in the same ratio to each other as the NH_3/H_2O abundance ratio in the lower dry atmosphere. The ammonia concentration in solution at the cloud base can be determined from equations 5 and 6 in Table I. With the knowledge of the ammonia concentration P_2 is calculated and compared with the partial pressure of H_2O in the atmosphere. If the partial pressure of H_2O is greater than or equal to P_2 then condensation will occur. At the cloud base there is a possibility that the condensate freezes; therefore a check for freezing has to be made. Freezing occurs when $\overline{P}_2 < P_2$ where $\overline{P}_2$ is P_2 of Eq. 1 in Table I.

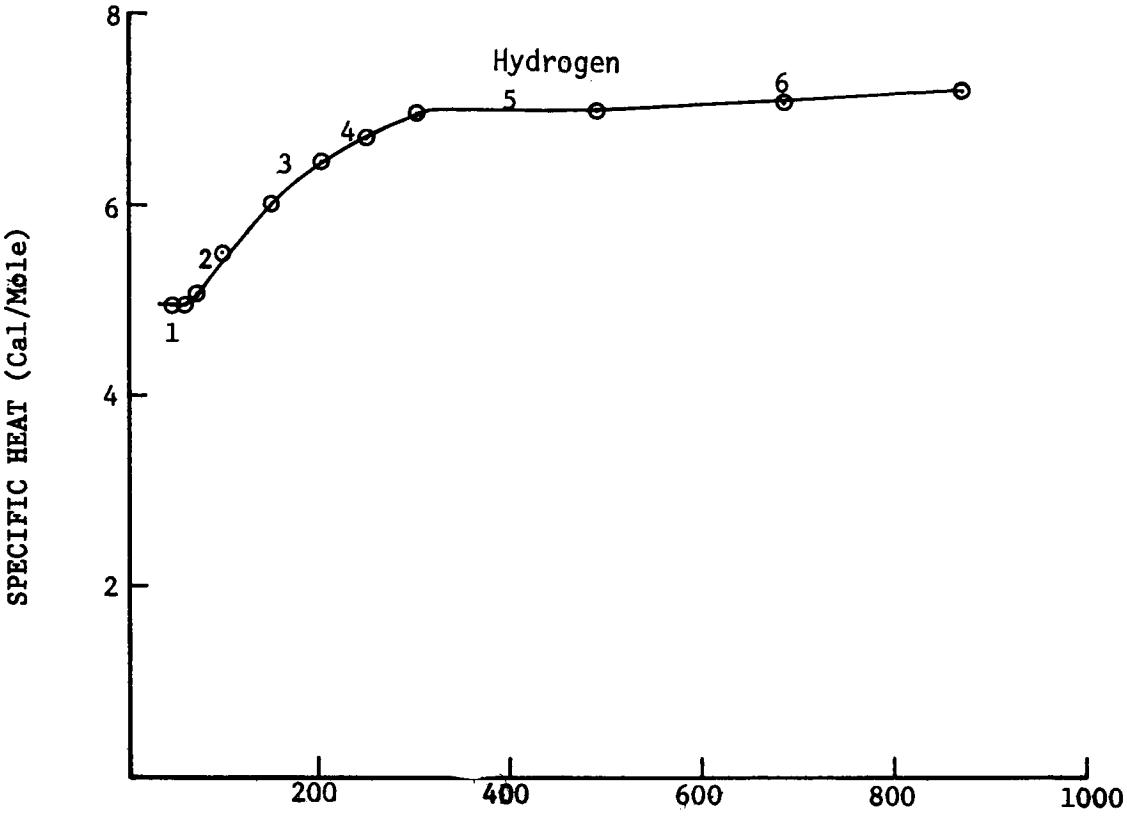
3) The incremental changes in the temperature and pressure are calculated in the following manner; where J corresponds to the previous altitude and I corresponds to the present altitude:

   a) below the level of condensation

$$T_I = T_J - \frac{\mu G \times 10^5}{Cp_J} \qquad \text{Eq. 23}$$

TABLE II. PARAMETERS USED IN NASA'S MODEL ATMOSPHERES FOR JUPITER, SATURN, URANUS, AND NEPTUNE (Ref's 1, 3, 4)

PARAMETER		JUPITER 'COOL' MODEL	JUPITER NOMINAL MODEL	SATURN NOMINAL MODEL	URANUS NOMINAL MODEL	NEPTUNE NOMINAL MODEL
Composition (Molar fraction)	H_2	0.68454	0.86578	0.88572	0.88572	0.88572
	He	0.31057	0.13214	0.11213	0.11000	0.11000
	CH_4	0.00145	0.00062	0.00063	0.03000	0.03000
	NH_3	0.00035	0.00015	0.00015	0.00015	0.00015
	H_2O	0.00240	0.00102	0.00105	0.00100	0.00100
	Ne	0.00031	0.00013	0.00013	0.00013	0.00013
	Others	0.00038	0.00016	0.00019	0.00019	0.00019
$\bar{\mu}$ (grams/mole)		2.70	2.30	2.27	2.68	2.68
G (cm/sec^2)		2700	2500	1050	810	1100
Reference Temperature (K^o)		405.3	398.169	292.173	351	378
Reference Pressure (ATM)		100.77	10.906	8.366	9.0	27.7
Reference Altitude (Km). Zero altitude is a one atmosphere.		-133	-52	-156	-331	-282



REGION	EQUATION	DOMAIN
1.	$Cp = 4.96$	$T \leq 60$
2.	$Cp = .011T + 4.38$	$60 < T \leq 150$
3.	$Cp = 7.4 \times 10^{-3}T + 4.92$	$150 < T \leq 200$
4.	$Cp = 5.5 \times 10^{-3}T + 5.3$	$200 < T \leq 300$
5.	$Cp = 6.96$	$300 < T \leq 473$
6.	$Cp = 6.75 \times 10^{-4}T + 6.641$	$T > 473$

Figure 2. Specific Heat, for Hydrogen. The specific heat for He is 4.98 cal/mole and the specific heat for the Jupiter 'cool' atmosphere is 8.94 cal/mole.

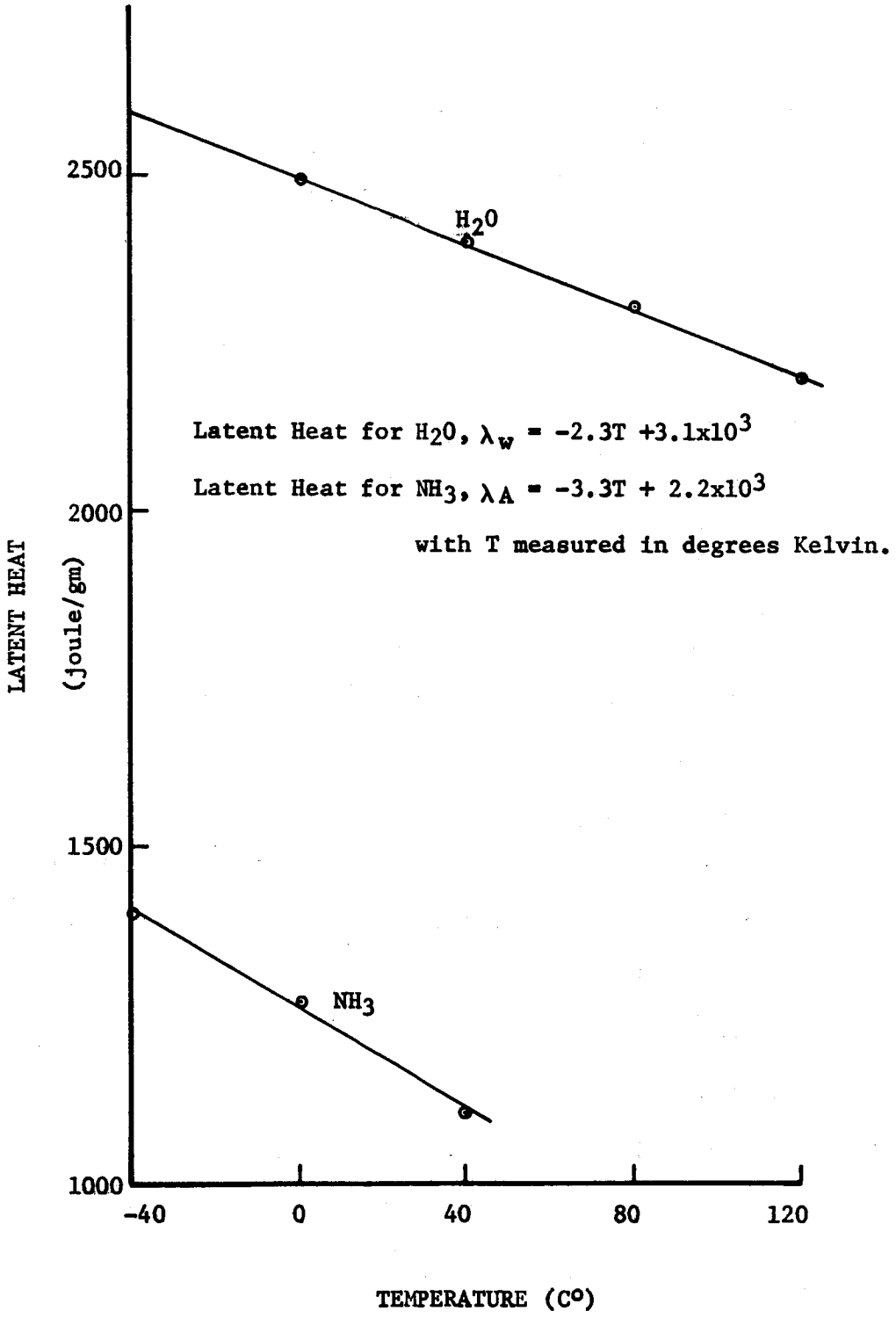


Figure 3. Latent Heat Release of Condensation for Water and Ammonia

cgs units are used and 10^5 is the altitude increment in centimeters.

$$P_I = P_J \text{ EXP } \left[\frac{-\mu G x 10^5}{RT}\right] \qquad \text{Eq. 24}$$

where $\overline{T} = 1/2\ (T_I + T_J)$

b) after condensation has occurred but below the ammonia clouds:

$$T_I = T_J - \frac{\mu G x 10^5}{Cp_J + \lambda_{BJ}\left[\frac{\lambda_{BJ}\ \chi_{WJ}}{(1-C_J)RT_J^2} - \frac{\chi_{BJ}}{T}\right]} \qquad \text{Eq. 25}$$

where $\chi_B = \chi_W + \chi_A$

c) for the ammonia clouds

$$T_I = T_J - \frac{\mu G x 10^5}{Cp_J + \lambda_{BJ}\left[\frac{\lambda_{BJ}\ \chi_{AJ}}{C_J\ RT_J^2} - \frac{\chi_{BJ}}{T}\right]} \qquad \text{Eq. 26}$$

4) Calculate ammonia concentration in solution.

a) for region where water is the prime condensate χ_A is almost constant, thus

$$P_{AI} = \chi_{AJ} P_I \qquad \text{Eq. 27}$$

where P_{AI} is the partial pressure of ammonia. Then the ammonia concentration is calculated with the use of Equation 6, Table I where $P_3 = P_{AI}$.

b) for the region where ammonia is the prime condensate χ_W is almost constant, thus

$$P_{WI} = \chi_{WJ} P_I \qquad \text{Eq. 28}$$

The ammonia concentration in solution is calculated with the use of Eq. 5 - Table I where $P_2 = P_{WI}$.

5) Calculate water and ammonia vapor pressures in solution and check for freezing. The vapor pressure of water is calculated from Eq. 5 - Table I. Now calculate the concentration of water in the atmosphere by $\chi_W = P_2/P$. Now, a better calculation of the vapor pressure of ammonia can be calculated with the use of Equation 19.

$$P_A = \chi_A P = P\left[\frac{\lambda_B \chi_W C}{(1-C)RT^2} - \frac{\chi_B}{T}\right] \qquad \text{Eq. 29}$$

Theoretically if the above partial pressures are greater than the partial pressures predicted by Eq's 1, 2, 3, or 4 in Table I, then the system is in one of the frozen states. As it turns out the equations in Table I do not give accurate enough predictions to predict the phases in the above manner; therefore, the phases were determined by checking to see if the coordinates defined by $\chi_W P$ and $\chi_A P$ are within the scalloped curves as illustrated in Figure 1. When the H_2O - NH_3 system is within one of the solid phases, χ_W and χ_A are determined by the appropriate equations in Table I.

6) The cloud density, D, was determined in the following manner:

$$D = \left[\frac{(\chi_{AJ} - \chi_{AI}) + (\chi_{WJ} - \chi_{WI})}{Gd}\right]\overline{P} \qquad \text{Eq. 30}$$

where d is the altitude increment and $\overline{P} = 1/2(P_I + P_J)$.

IV. Results

Pertinent results specifying the cloud structures are presented in Tables III through VII. The altitude values found in the tables correspond with a particular cloud base which also coincides with the maximum cloud density. The prominent clouds are illustrated in Figures 4 through 8.

TABLE III. JUPITER NOMINAL CLOUD MODEL

Atmos. Comp.

H_2 - 86.58%

He - 13.24%

CH_4 - 0.06%

NH_3 - 0.01%

H_2O - 0.10%

Ref. Temp - 305 (^oK)

Ref. Pres - 4.53×10^6 (dynes/cm^2)

Ref. Alt - -52 (Km)

Gravitational Accel - 2500 (cm/sec^2)

Molecular Weight - 2.3 (gm/mole)

ALT (1)	PRESSURE (dynes/cm^2)	TEMP (^oK)	CLOUD DENSITY (gm/liter)	PHASE
-30	2.65×10^6	260.4	1.2×10^{-3}	Solid H_2O
12	6.90×10^5	171.4	5.0×10^{-8}	Solid (NH_3) H_2O
17	5.61×10^5	160.0	1.6×10^{-9}	Solid $(NH_3)_2$ H_2O
24	4.09×10^5	144.2	6.5×10^{-5}	Solid NH_3

(1) Zero altitude at one atmosphere.

TABLE IV. JUPITER 'COOL'CLOUD MODEL

Atmos. Comp.

H_2 - 68.49%

He - 31.10%

CH_4 - 0.14%

NH_3 - 0.03%

H_2O - 0.24%

Ref. Temp - 405 (^oK)

Ref. Pres - 1.02×10^8 (dynes/cm^2)

Gravitational Accel - 2700 (cm/sec^2)

Molecular Weight - 2.7 (gm/mole)

Specific heat - 8.94 (cal/mole)

Alt[1] (Km)	PRESSURE (dynes/cm^2)	TEMP (^oK)	CLOUD DENSITY (gm/liter)	PHASE
-83	2.99×10^7	308.7	2.2×10^{-2}	(0.8 - 2.7)% Solution[2]
-63	1.65×10^7	272.6	3.1×10^{-3}	Solid H_2O
-26	4.26×10^6	201.6	4.9×10^{-6}	(29.1 - 39.8)% Solution[2]
-16	2.72×10^6	182.2	2.3×10^{-7}	Solid $(NH_3)H_2O$
-11	2.13×10^6	172.5	1.2×10^{-8}	Solid $(NH_3)_2 H_2O$
- 2	1.33×10^6	155.3	3.1×10^{-4}	Solid NH_3

(1) Zero altitude at one atmosphere.

(2) Percentage of ammonia in solution.

TABLE V. SATURN CLOUD MODEL

Atmos. Comp.

H_2 - 88.59%

He - 11.23%

CH_4 - 0.06%

NH_3 - 0.01%

H_2O - 0.11%

Ref. Temp - 292 ^oK

Ref. Pres - 8.48×10^6 (dynes/cm^2)

Ref. Alt - -156 (Km)

Gravitational Accel - 1050 (cm/sec^2)

Molecular Weight - 2.27 (gm/mole)

ALT (1) (Km)	PRESSURE (dynes/cm^2)	TEMP (K^o)	CLOUD DENSITY (gm/liter)	PHASE
-134	6.79×10^6	273.7	3.0×10^{-3}	Solid H_2O
- 27	1.78×10^6	181.5	2.5×10^{-7}	(33.4 - 36.4)% Solution (2)
- 21	1.62×10^6	176.0	1.2×10^{-7}	Solid (NH_3) H_2O
- 10	1.35×10^6	165.8	4.2×10^{-9}	Solid $(NH_3)_2$ H_2O
7	9.95×10^5	149.9	1.7×10^{-4}	Solid NH_3

(1) Zero altitude at one atmosphere.

(2) Percentage of ammonia in solution.

TABLE VI. URANUS CLOUD MODEL

Atmos. Comp.

H_2 - 85.87%

He - 11.02%

CH_4 - 3.00%

NH_3 - 0.01

H_2O - 0.10

Ref. Temp - 351 (Ko)

Ref. Pres - 9.29×10^7 (dynes/cm^2)

Ref. Alt - -331 (Km)

Gravitational Accel - 810 (cm/sec^2)

Molecular Weight - 2.68 (gm/mole)

Alt[1] (Km)	PRESSURE (dynes/cm^2)	TEMP (K^o)	CLOUD DENSITY (gm/liter)	PHASE
-274	5.93×10^7	306.1	2.8×10^{-2}	(0.9 - 2.9) % Solution[2]
-231	4.04×10^7	273.5	4.5×10^{-3}	Solid H_2O
-154	1.78×10^7	210.8	2.1×10^{-5}	(26.8 - 42.3) % Solution[2]
-127	1.25×10^7	188.0	6.6×10^{-7}	Solid (NH_3) H_2O
-115	1.06×10^7	177.6	4.3×10^{-8}	Solid $(NH_3)_2$ H_2O
- 98	8.17×10^6	162.9	1.4×10^{-3}	Solid NH_3

(1) Zero altitude at one atmosphere.

(2) Percentage of ammonia in solution.

TABLE VII. NEPTUNE CLOUD MODEL

Atmos. Comp.

H_2 - 85.87%

He - 11.02%

CH_4 - 3.00%

NH_3 - 0.01%

H_2O - 0.10%

Ref. Temp. - 378 (K^o)

Ref. Press - 2.87×10^8 (dynes/cm^2)

Ref. Alt - -282 (Km)

Gravitational Accel - 1100 (cm/sec^2)

Molecular Weight - 2.68 (gm/mole)

Alt[1] (Km)	PRESSURE (dynes/cm^2)	TEMP (K^o)	CLOUD DENSITY (gm/liter)	PHASE
-233	1.77×10^8	326.0	7.4×10^{-2}	(0.9 - 7.3)% Solution[2]
-174	8.89×10^7	265.3	2.5×10^{-3}	Solid H_2O
-146	5.91×10^7	233.3	2.7×10^{-4}	(20.7 - 47.6)% Solution[2]
-109	3.21×10^7	191.2	7.3×10^{-7}	Solid $(NH_3)\ H_2O$
-103	2.87×10^7	184.3	1.3×10^{-7}	Solid $(NH_3)_2 H_2O$
- 89	2.17×10^7	167.9	3.1×10^{-3}	Solid NH_3

(1) Zero altitude at one atmosphere.

(2) Percentage of ammonia in solution.

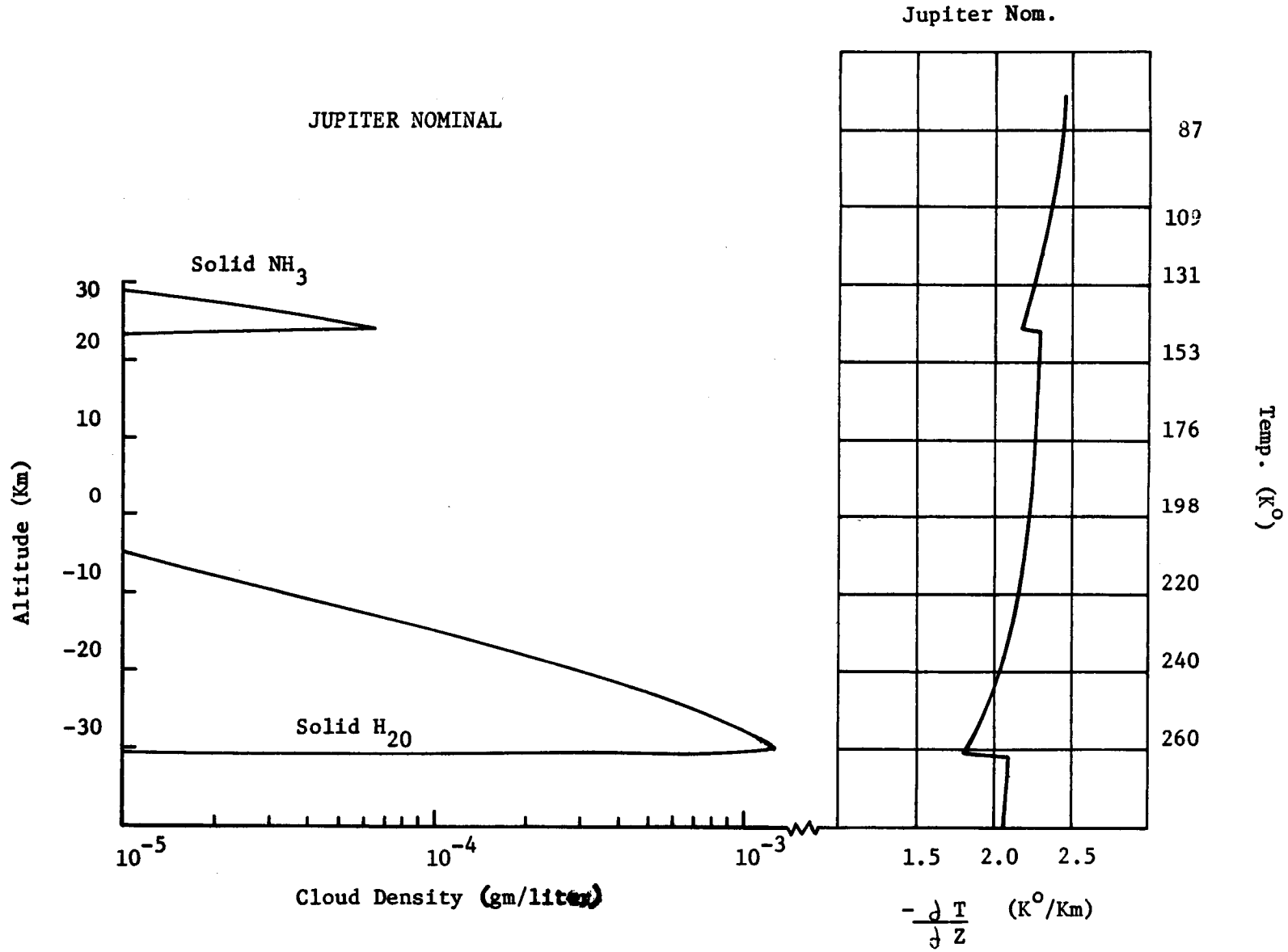
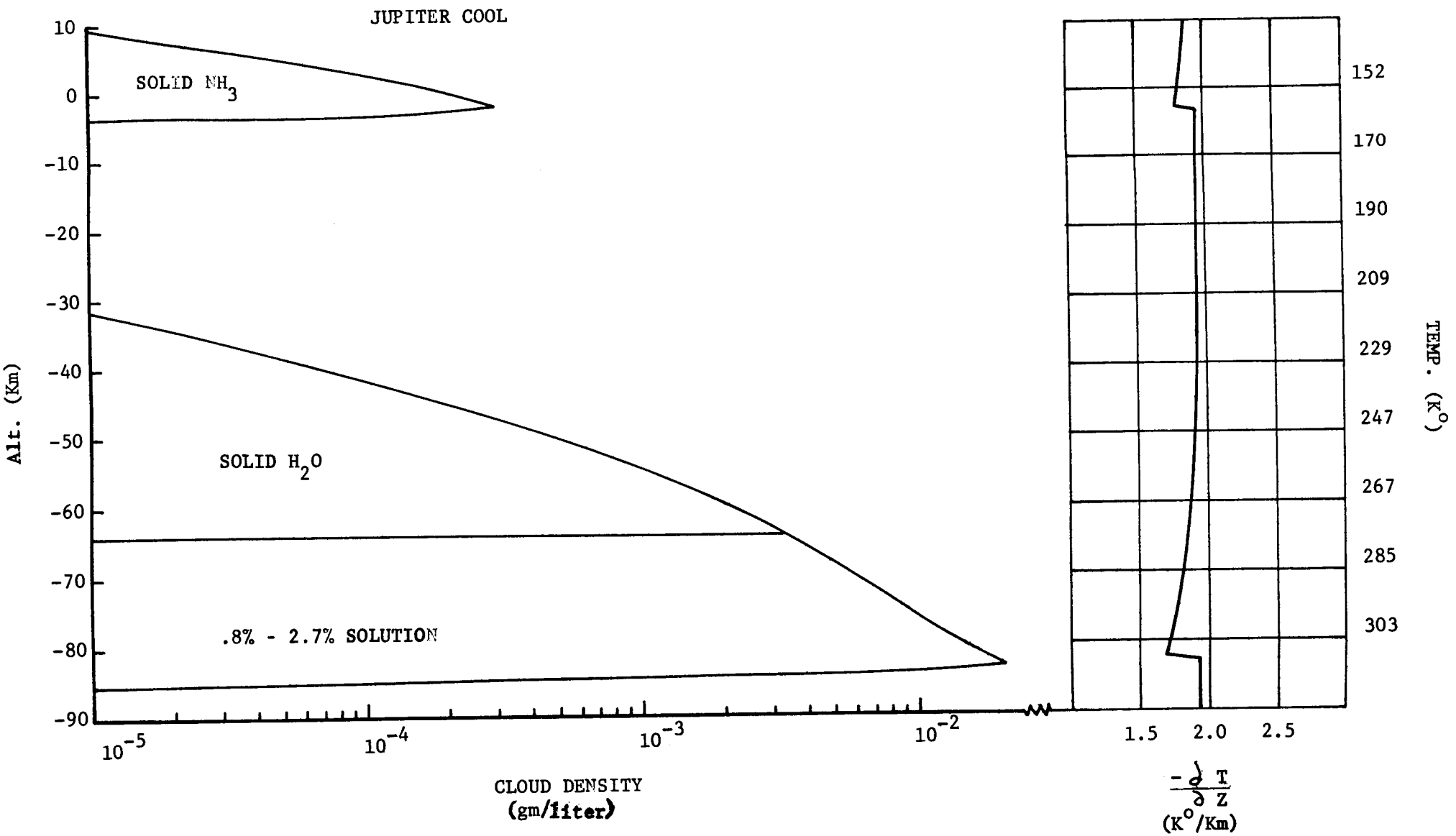


Figure 4. Cloud densities and the wet-adiabatic lapse rate for Jupiter nominal model atmosphere.


JUPITER COOL
SOLID NH_3
SOLID H_2O
.8% - 2.7% SOLUTION
Alt. (Km)
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
10^{-5}
10^{-4}
10^{-3}
10^{-2}
CLOUD DENSITY
(gm/liter)
152
170
190
209
229
247
267
285
303
TEMP. (K^o)
1.5
2.0
2.5
$-\frac{\partial T}{\partial Z}$
(K^o/Km)

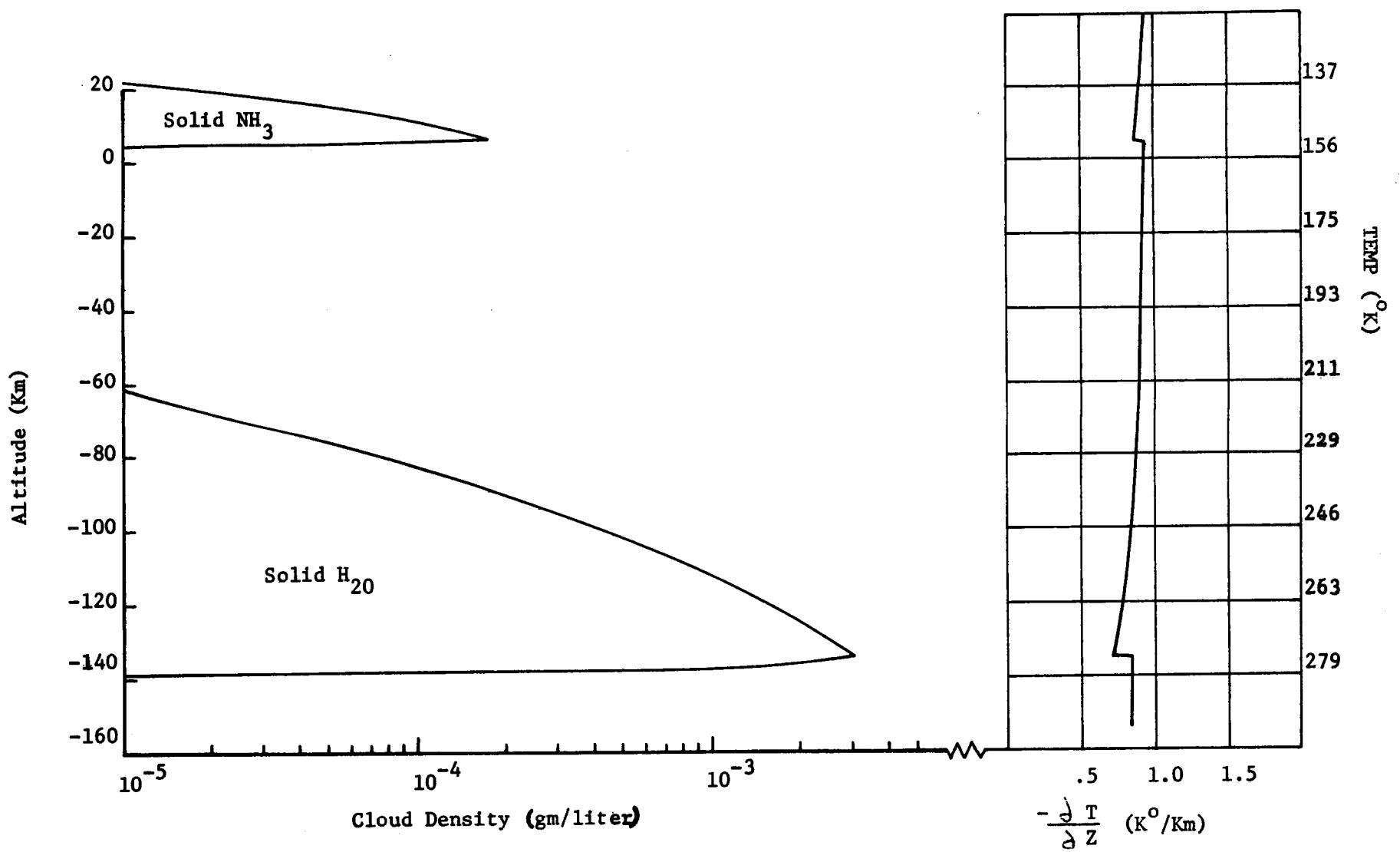


Figure 6. Cloud densities and the wet-adiabatic lapse rate for Saturn nominal model atmosphere.

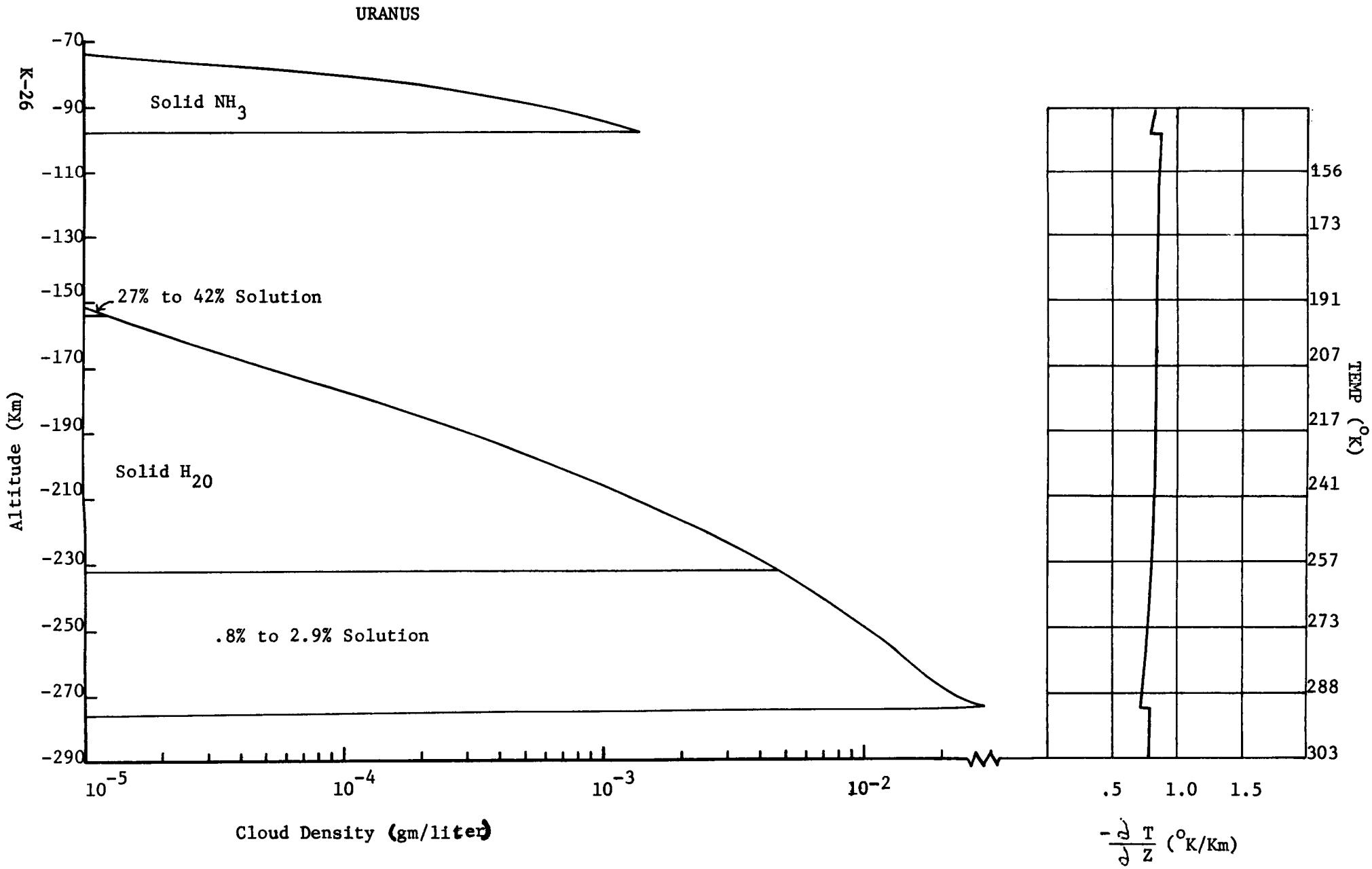


Figure 7. Cloud densities and the wet-adiabatic lapse rate for Uranus nominal model atmosphere.

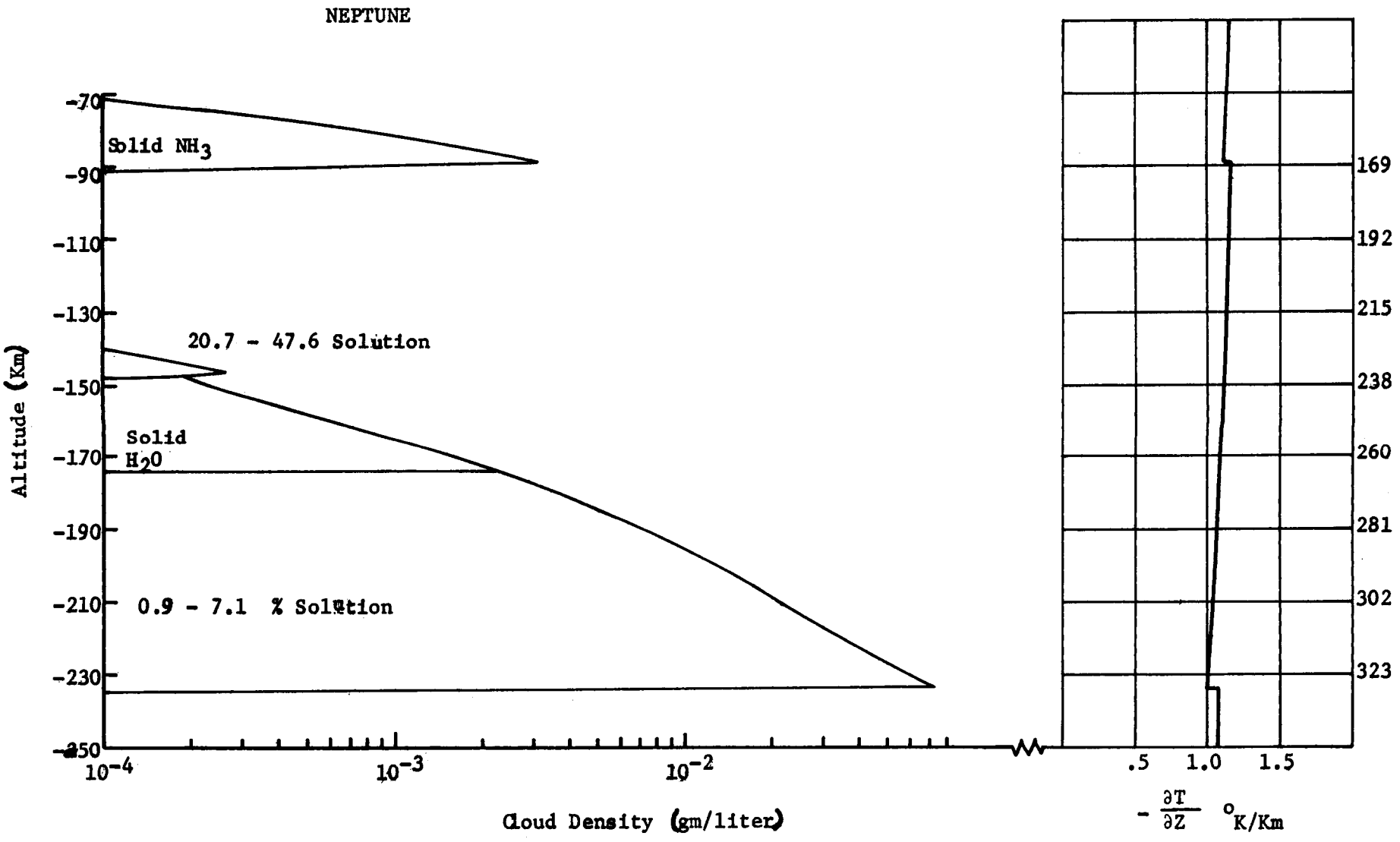


Figure 8. Cloud densities and the wet-adiabatic lapse rate for Neptune nominal model atmosphere.

V. REFERENCES

1) John S. Lewis, "The Clouds of Jupiter and the NH_3-H_2O and NH_3-H_2S Systems", Icarus, 10, 365 (1969).

2) C. Haudenschild, "Multi-phase Ammonia Water System", JPL Space Programs Summary 37-64 Vol. III.

3) "The Planet Jupiter (1970)", NASA SP-8069 (Dec. 1971).

4) "Preliminary Model Atmospheres for the Planets Uranus and Neptune", JPL Section Document 131-17 (Nov. 1971).

5) "The Planet Saturn (1970)", NASA Space Vehicle Design Criteria (Environment) Preliminary Information.

APPENDIX L

VERTICAL DESCENT PROGRAM FOR SCIENCE INSTRUMENT SIMULATION (DATAT) DESCENT RUNS FOR JUPITER AND SATURN

K. W. Ledbetter
and
A. R. Barger

June 8, 1972

```
$INPT
 TITLE=50NSURVIVABLE JUPITER PROBE TASK 3 DESCENT RUNS
 $NOTE=50M BAL. COEF.  0.65/0.09/1.50        SEP 10 BARS
 BS=0.09,
 IATM=1,
 $START=71454.,      TSTART=0,
 $STOP=71337.,     TSTOP=1.0E+08,
 DR=3.,
 STOPC= 6800.,
 FREQ=2.4E+09,     FZA=25.,
 $NAME=6H  TEMP,6H PRESS,6H  TEMP,6H PRESS,6H ACCEL,6H ACCEL,
      6H ACCEL,6H ACCEL,6HM SPEC,6HM SPEC,6HM SPEC,6HM SPEC,
 OTI(1,1)=3.,3.5,4.,5.,7.,8.,10.,15.,30.,40.,50.,60.,
 OTI(1,2)=3.,3.5,4.,5.,7.,8.,10.,15.,30.,40.,50.,60.,
 OPS(1,1)=10.,10.,10.,10.,30.,30.,30.,30.,400.,400.,400.,400.,
 OPS(1,2)=10.,10.,10.,10.,30.,30.,30.,30.,400.,400.,400.,400.,
 NSTAC=2,
 $CHG(2)=1.50,
 $CHG(2)=71372.,
 $
```

SURVIVABLE JUPITER PROBE TASK 3 DESCENT RUNS
JPL MONOGRAPH JUPITER COOL/DENSE ATMOSPHERE
BALLISTIC COEFFICIENT = .090, INITIAL TIME = 0. SECONDS AT 71454.000 KM RADIUS

CAL. COEF. 0.65/0.09/1.50 SEP 10 BARS

SAMPLE INTERVALS (SECONDS)

TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
3.000	3.500	4.000	5.000	7.000	8.000	10.000	15.000	30.000	40.000	50.000	60.000

BITS PER SAMPLE

TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
10.000	10.000	10.000	10.000	30.000	30.000	30.000	30.000	400.000	400.000	400.000	400.000

NO OF PREVIOUS MEASUREMENTS

TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

REQUIRED BIT RATE = 61.7262 BITS/SECOND

ENTRY DATA IN STORAGE = 6800.0 BITS

SURVIVABLE JUPITER PROBE TASK 3 DESCENT RUNS
JPL MONOGRAPH JUPITER COOL/DENSE ATMOSPHERE
BALLISTIC COEFFICIENT = .090, INITIAL TIME = 0. SECONDS AT 71454.000 KM RADIUS

BAL. COEF. 0.65/0.09/1.50 SEP 18 BARS

RADIUS 71454.000 KM	ALTITUDE	32.000 KM	PRESSURE	.093324 BARS	TEMPERATURE	108.000 KELVIN						
		104.987 KFT		.092103 ATM		-265.270 FAHRENHEIT						
TIME 0. SEC	VELOCITY	164.878 METER/SEC	DYN P	.003815 BARS								
0. MIN		1.2485 MB/SEC	DOPPLER	1.195383E+03 CPS								
0. HRS		540.912 FT/SEC	MACH NO	.233428								

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KM/MEAS	.48971	.57040	.65081	.81087	1.12789	1.28489	1.56592	2.35674	4.50772	5.84404	7.11163	8.31721
MEAS/KM	2.0420	1.7532	1.5365	1.2332	.8866	.7783	.6386	.4243	.2218	.1711	.1406	.1202
BARS/MEAS	.00378	.00442	.00506	.00634	.00894	.01025	.01250	.01966	.04120	.05660	.07284	.08991
MEAS/BAR	264.4353	226.2841	197.6717	157.6170	111.8475	97.5477	77.5328	50.8652	24.2726	17.6673	13.7287	11.1217
DEGK/MEAS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MEAS/DEGK	R	R	R	R	R	R	R	R	R	R	R	R
MEAS/PSCHT	25.17476	21.61380	18.94305	15.20392	10.93039	9.59482	7.72487	5.23101	2.73481	2.10941	1.73340	1.48212

RADIUS 71451.000 KM	ALTITUDE	29.000 KM	PRESSURE	.119036 BARS	TEMPERATURE	106.000 KELVIN						
		95.144 KFT		.117479 ATM		-265.270 FAHRENHEIT						
TIME 19.349 SEC	VELOCITY	145.988 METER/SEC	DYN P	.003815 BARS								
.32249 MIN		1.4101 MB/SEC	DOPPLER	1.058480E+03 CPS								
.005375 HRS		478.963 FT/SEC	MACH NO	.206694								

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	7.45	6.53	5.84	4.87	3.76	3.42	2.93	2.29	1.54	1.48	1.39	1.32
KM/MEAS	.43412	.50574	.57714	.71934	1.00180	1.14109	1.41829	2.09797	4.03132	5.24080	6.36371	7.49508
MEAS/KM	2.3035	1.9773	1.7327	1.3902	.9987	.8764	.7051	.4767	.2481	.1908	.1564	.1334
BARS/MEAS	.00427	.00499	.00571	.00715	.01007	.01154	.01451	.02208	.04605	.06307	.08093	.09962
MEAS/BAR	234.3778	200.6007	175.2687	139.8056	99.2814	86.6198	68.8971	45.2799	21.7159	15.8555	12.3570	10.0385
DEGK/MEAS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MEAS/DEGK	R	R	R	R	R	R	R	R	R	R	R	R
MEAS/PSCHT	28.39636	24.37520	21.35930	17.13697	12.31125	10.80313	8.69181	5.87574	3.05776	2.35204	1.92789	1.64457

RADIUS 71448.000 KM	ALTITUDE	26.000 KM	PRESSURE	.151834 BARS	TEMPERATURE	106.000 KELVIN						
		85.302 KFT		.149849 ATM		-265.270 FAHRENHEIT						
TIME 41.202 SEC	VELOCITY	129.267 METER/SEC	DYN P	.003815 BARS								
.68669 MIN		1.5926 MB/SEC	DOPPLER	9.372472E+02 CPS								
.011445 HRS		424.105 FT/SEC	MACH NO	.183021								

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	14.73	12.77	11.30	9.24	6.89	6.15	5.12	3.75	2.37	2.03	1.82	1.69
KM/MEAS	.38478	.44833	.51172	.63801	.88866	1.01304	1.25992	1.86653	3.60162	4.69401	5.74803	6.77335
MEAS/KM	2.5989	2.2305	1.9542	1.5674	1.1253	.9871	.7937	.5358	.2777	.2130	.1742	.1476
BARS/MEAS	.00481	.00562	.00644	.00807	.01135	.01301	.01634	.02482	.05153	.07038	.09086	.11121
MEAS/BAR	207.7079	177.8040	155.3765	123.9793	88.1003	76.8897	61.1973	40.2832	19.4068	14.2094	11.1039	8.9921
DEGK/MEAS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	.34670
MEAS/DEGK	R	R	R	R	R	R	R	R	R	R	R	2.8843
MEAS/PSCHT	32.03463	27.49374	24.08805	19.32002	13.87066	12.16766	9.78334	6.60377	3.42230	2.62582	2.14728	1.81975

SURVIVABLE JUPITER PROBE TASK 3 DESCENT RUNS
JPL MONOGRAPH JUPITER COOL/DENSE ATMOSPHERE
BALLISTIC COEFFICIENT = .090, INITIAL TIME = 0. SECONDS AT 71454.000 KM RADIUS

BAL. COEF. 0.65/0.09/1.50 SEE 10 BARS

RADIUS 71445.000 KM	ALTITUDE	23.000 KM	PRESSURE	.193675 BARS	TEMPERATURE	108.000 KELVIN						
		75.459 KFT		.191142 ATM		-265.270 FAHRENHEIT						
TIME 65.681 SEC	VELOCITY	114.460 METER/SEC	DYN P	.003815 BARS								
1.09401 MIN		1.7987 MB/SEC	DOPPLER	8.298911E+02 CPS								
.319300 HRS		375.526 FT/SEC	MACH NO	.162057								
INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	22.96	19.82	17.47	14.18	10.41	9.24	7.59	5.39	3.20	2.65	2.32	2.10
KM/MEAS	.34101	.39739	.45764	.56576	.78848	.89909	1.11883	1.65975	3.21476	4.21656	5.19193	6.14064
MEAS/KM	2.9325	2.5164	2.2044	1.7675	1.2683	1.1122	.8938	.6025	.3111	.2372	.1926	.1628
BARS/MEAS	.00543	.00635	.00726	.00910	.01279	.01466	.01840	.02792	.05772	.07893	.10091	.12359
MEAS/BAR	184.0490	157.5752	137.7197	109.9227	78.1572	68.2316	54.3374	35.8183	17.3257	12.6696	9.9094	8.0912
DECK/MEAS	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.23313	3.18386	5.04013
MEAS/DECK	R	R	R	R	R	R	R	R	R	.8109	.3141	.1984
MEAS/PSCHT	36.14351	31.01566	27.16975	21.78543	15.63175	13.70866	11.01622	7.42588	3.83383	2.92535	2.38435	2.02610

RADIUS 71442.000 KM	ALTITUDE	20.000 KM	PRESSURE	.247050 BARS	TEMPERATURE	108.000 KELVIN						
		65.617 KFT		.243819 ATM		-265.270 FAHRENHEIT						
TIME 93.752 SEC	VELOCITY	101.349 METER/SEC	DYN P	.003815 BARS								
1.56254 MIN		2.0316 MB/SEC	DOPPLER	7.348244E+02 CPS								
.026042 HRS		332.509 FT/SEC	MACH NO	.143493								
INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	32.25	27.79	24.44	19.75	14.39	12.72	10.38	7.25	4.13	3.34	2.88	2.56
KM/MEAS	.30219	.35219	.40210	.50160	.69977	.79850	.99507	1.40137	2.89888	3.81192	4.70178	5.57016
MEAS/KM	3.3092	2.8394	2.4870	1.9936	1.4290	1.2523	1.0050	.6750	.3450	.2623	.2127	.1795
BARS/MEAS	.00613	.00716	.00819	.01026	.01443	.01653	.02074	.03139	.06431	.08707	.11047	.13451
MEAS/BAR	163.0682	139.6300	122.0516	97.4424	69.2934	60.5004	48.2085	31.8539	15.5490	11.4856	9.0525	7.4341
DECK/MEAS	0.	0.	0.	0.	.99954	.39701	.79014	1.76275	4.57004	6.34398	8.07178	9.75790
MEAS/DECK	R	R	R	R	5.0125	2.5189	1.2656	.5673	.2188	.1576	.1239	.1025
MEAS/PSCHT	40.78393	34.99318	30.65011	24.56975	17.61419	15.44122	12.40318	8.35954	4.32212	3.31239	2.70569	2.30049

RADIUS 71439.000 KM	ALTITUDE	17.000 KM	PRESSURE	.313821 BARS	TEMPERATURE	112.767 KELVIN						
		55.774 KFT		.309717 ATM		-256.690 FAHRENHEIT						
TIME 124.852 SEC	VELOCITY	91.889 METER/SEC	DYN P	.003815 BARS								
2.08087 MIN		2.7411 MB/SEC	DOPPLER	6.662411E+02 CPS								
.034681 HRS		301.475 FT/SEC	MACH NO	.127321								
INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	42.62	36.67	32.21	25.97	18.84	16.61	13.46	9.32	5.16	4.12	3.50	3.08
KM/MEAS	.23453	.32006	.36554	.45630	.63708	.72711	.90645	1.35070	2.65014	3.49063	4.31211	5.11584
MEAS/KM	4.2636	3.1244	2.7357	2.1916	1.5697	1.3753	1.1032	.7404	.3773	.2865	.2319	.1955
BARS/MEAS	.00675	.00788	.00901	.01128	.01584	.01813	.02272	.03432	.07002	.09459	.11977	.14556
MEAS/BAR	148.1187	126.8712	110.9357	88.6263	63.1306	55.1636	44.0103	29.1415	14.2816	10.5719	8.3492	6.8699
DECK/MEAS	.53381	.62229	.71058	.98681	1.23784	1.41264	1.76086	2.62345	5.14652	6.77847	8.37351	9.93408
MEAS/DECK	1.8733	1.6070	1.4073	1.1276	.8079	.7079	.5679	.3812	.1943	.1475	.1194	.1007
MEAS/PSCHT	46.98101	40.31280	35.31152	28.30987	20.30763	17.80683	14.30555	9.63657	4.96511	3.79577	3.09327	2.62423

SURVIVABLE JUPITER PROBE TASK 3 DESCENT RUNS
JPL MONOGRAPH JUPITER COOL/DENSE ATMOSPHERE
BALLISTIC COEFFICIENT = .090, INITIAL TIME = 0. SECONDS AT 71454.000 KM RADIUS

BAL. COEF. 0.05/0.09/1.50 SEP 10 BARS

RADIUS 71436.000 KM		ALTITUDE	14.000 KM		PRESSURE	.393925 BARS		TEMPERATURE	118.593 KELVIN			
			45.932 KFT			.388773 ATM			-246.203 FAHRENHEIT			
TIME	158.588 SEC	VELOCITY	84.112 METER/SEC		DYN P	.003816 BARS						
	2.64980 MIN		2.4490 MB/SEC		DOPPLER	6.0984938+02 CPS						
	.044163 HRS		275.957 FT/SEC		MACH NO	.113645						

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	54.00	46.43	40.75	32.80	23.71	20.87	16.90	11.60	6.30	4.97	4.18	3.65
KM/MEAS	.25143	.29315	.33483	.41804	.58388	.66650	.83117	1.23954	2.43765	3.21528	3.97724	4.72444
MEAS/KM	3.9773	3.4112	2.9866	2.3921	1.7127	1.5004	1.2031	.8067	.4102	.3110	.2514	.2117
BARS/MEAS	.00737	.00861	.00984	.01232	.01729	.01978	.02478	.03740	.07612	.10266	.12979	.15749
MEAS/BAR	135.6315	116.1456	101.6012	81.1834	57.8492	50.5575	40.3496	26.7406	13.1379	9.7410	7.7050	6.3495
DECK/MEAS	.48819	.56921	.65014	.81170	1.13369	1.29412	1.61386	2.40678	4.73310	6.24300	7.72643	9.18160
MEAS/DECK	2.0484	1.7569	1.5381	1.2320	.8821	.7727	.6196	.4155	.2113	.1602	.1294	.1089
MEAS/PSCHT	53.02705	46.26656	40.52117	32.47755	23.28465	20.41178	16.38962	11.02822	5.66064	4.31793	3.51149	2.97324

RADIUS 71493.000 KM		ALTITUDE	11.000 KM		PRESSURE	.489121 BARS		TEMPERATURE	124.418 KELVIN			
			36.089 KFT			.482725 ATM			-235.718 FAHRENHEIT			
TIME	196.201 SEC	VELOCITY	77.319 METER/SEC		DYN P	.003816 BARS						
	3.27001 MIN		2.6644 MB/SEC		DOPPLER	5.6059746+02 CPS						
	.054500 HRS		253.671 FT/SEC		MACH NO	.104992						

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	56.40	57.06	50.05	40.24	29.03	25.53	20.62	14.08	7.54	5.91	4.92	4.27
KM/MEAS	.23122	.26962	.30797	.38457	.53727	.61339	.76516	1.14189	2.25003	2.97142	3.67978	4.37581
MEAS/KM	4.3248	3.7089	3.2470	2.6003	1.8613	1.6303	1.3069	.8757	.4444	.3365	.2718	.2285
BARS/MEAS	.00802	.00936	.01070	.01339	.01879	.02150	.02693	.04060	.08246	.11106	.14022	.16994
MEAS/BAR	124.7126	106.8401	93.4358	74.6698	53.2235	46.5217	37.1395	24.6310	12.1271	9.0038	7.1315	5.8845
DECK/MEAS	.44896	.52351	.59803	.74719	1.04459	1.19283	1.48929	2.22208	4.36019	5.78509	7.16463	8.52022
MEAS/DECK	2.2274	1.9102	1.6722	1.3383	.9573	.8383	.6715	.4500	.2293	.1729	.1396	.1174
MEAS/PSCHT	61.49826	52.75620	46.19962	37.02035	26.52960	23.25117	18.66126	12.54092	6.41865	4.88692	3.96717	3.35343

RADIUS 71440.000 KM		ALTITUDE	8.000 KM		PRESSURE	.601341 BARS		TEMPERATURE	130.258 KELVIN			
			26.247 KFT			.593477 ATM			-225.205 FAHRENHEIT			
TIME	216.602 SEC	VELOCITY	71.353 METER/SEC		DYN P	.003817 BARS						
	3.94337 MIN		2.8877 MB/SEC		DOPPLER	5.1734366+02 CPS						
	.065723 HRS		234.098 FT/SEC		MACH NO	.096989						

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	79.87	68.60	60.15	49.32	34.80	30.58	24.66	16.77	8.89	6.92	5.73	4.94
KM/MEAS	.21346	.24893	.28435	.35511	.49625	.56662	.70695	1.05570	2.08366	2.75457	3.41460	4.06428
MEAS/KM	4.6847	4.0173	3.5167	2.8160	2.0151	1.7644	1.4145	.9472	.4799	.3630	.2929	.2460
BARS/MEAS	.00869	.01014	.01159	.01451	.02035	.02327	.02915	.04362	.08605	.11980	.15198	.18289
MEAS/BAR	115.1144	98.6276	86.2555	68.9403	49.1518	42.9680	34.3109	22.7689	11.2303	8.3476	6.6191	5.4678
DECK/MEAS	.41872	.48478	.56378	.69159	.96644	1.10349	1.37685	2.05597	4.05882	5.36619	6.65237	7.91636
MEAS/DECK	2.4055	2.0628	1.8058	1.4460	1.0347	.9062	.7263	.4864	.2464	.1864	.1503	.1263
MEAS/PSCHT	69.72181	59.80500	52.36737	41.95464	30.05421	26.33526	21.12863	14.18603	7.24171	5.50459	4.46169	3.76598

SERVIVABLE JUPITER PROBE TASK 3 DESCENT RUNS
JPL MONOGRAPH JUPITER COOL/DENSE ATMOSPHERE
BALLISTIC COEFFICIENT = .090, INITIAL TIME = 0. SECONDS AT 71494.000 KM RADIUS

BAL. COEF. 0.65/0.09/1.50 SEP 10 BARS

RADIUS 71427.000 KM	ALTITUDE	5.000 KM	PRESSURE	.732648 BARS	TEMPERATURE	136.103 KELVIN						
		16.404 KFT		.723068 ATM		-214.685 FAHRENHEIT						
TIME 240.303 SEC	VELOCITY	66.081 METER/SEC	DYN P	.003817 BARS								
4.67172 MIN		3.1187 MB/SEC	DOPPLER	4.791161E+02 CPS								
.177862 HRS		216.808 FT/SEC	MACH NO	.083342								

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	94.43	81.09	71.08	57.06	41.04	36.04	26.03	19.60	10.34	8.01	6.61	5.67
KM/MEAS	.10775	.23062	.26345	.32905	.45991	.52519	.65542	.97919	1.93542	2.56085	3.17713	3.78465
MEAS/KM	5.0568	4.3362	3.7957	3.0391	2.1743	1.9041	1.5257	1.0213	.5167	.3905	.3147	.2642
BARS/MEAS	.00778	.01095	.01252	.01566	.02196	.02511	.03144	.04736	.09587	.12885	.16234	.19634
MEAS/BAR	106.6243	91.3546	79.9023	63.8692	45.5458	39.8198	31.8037	21.1160	10.4308	7.7610	6.1599	5.0932
DECK/MEAS	.38535	.44939	.51338	.64120	.89621	1.02341	1.27719	1.90810	3.77145	4.98160	6.17308	7.34762
MEAS/DECK	2.5950	2.2252	1.9479	1.5596	1.1158	.9771	.7830	.5241	.2652	.2007	.1620	.1361
MEAS/PSCHT	78.61705	67.42962	59.03884	47.29185	33.76659	29.67113	23.70740	15.96578	8.13183	6.17258	4.99640	4.21179

RADIUS 71424.000 KM	ALTITUDE	2.000 KM	PRESSURE	.885260 BARS	TEMPERATURE	141.933 KELVIN						
		6.562 KFT		.873684 ATM		-204.190 FAHRENHEIT						
TIME 327.416 SEC	VELOCITY	61.392 METER/SEC	DYN P	.003817 BARS								
5.45693 MIN		3.3574 MB/SEC	DOPPLER	4.451232E+02 CPS								
.190949 HRS		201.419 FT/SEC	MACH NO	.078822								

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	110.14	94.56	82.85	66.48	47.77	41.93	33.74	22.83	11.91	9.19	7.55	6.46
KM/MEAS	.18777	.21432	.24485	.30584	.42755	.48827	.60945	.91089	1.80258	2.38690	2.96346	3.53256
MEAS/KM	5.4416	4.6659	4.0842	3.2697	2.3389	2.0481	1.6408	1.0978	.5548	.4190	.3374	.2831
BARS/MEAS	.01009	.01178	.01347	.01685	.02362	.02702	.03382	.05092	.10294	.13824	.17403	.21031
MEAS/BAR	99.0890	84.8860	74.2470	59.3530	42.3333	37.0145	29.5682	19.6402	9.7141	7.2337	5.7461	4.7549
DECK/MEAS	.35529	.41435	.47337	.59128	.82659	.94358	1.17827	1.76105	3.48499	4.60529	5.70599	6.79247
MEAS/DECK	2.8146	2.4134	2.1125	1.6912	1.2098	1.0597	.8487	.5678	.2869	.2171	.1753	.1472
MEAS/PSCHT	88.20098	75.64417	66.22663	53.04203	37.97378	33.26491	26.67239	17.88204	9.09032	6.89164	5.57187	4.69156

RADIUS 71421.000 KM	ALTITUDE	-1.000 KM	PRESSURE	1.061591 BARS	TEMPERATURE	147.709 KELVIN						
		-3.281 KFT		1.047709 ATM		-193.794 FAHRENHEIT						
TIME 398.685 SEC	VELOCITY	57.194 METER/SEC	DYN P	.003817 BARS								
6.39092 MIN		3.6044 MB/SEC	DOPPLER	4.146834E+02 CPS								
.185015 HRS		187.645 FT/SEC	MACH NO	.069242								

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	127.82	109.02	95.51	76.61	55.01	48.26	38.81	26.20	13.60	10.45	8.56	7.30
KM/MEAS	.17174	.19972	.22817	.28503	.39851	.45515	.56819	.84952	1.68293	2.23003	2.77062	3.30490
MEAS/KM	5.8237	5.0071	4.3827	3.5084	2.5093	2.1971	1.7600	1.1771	.5942	.4484	.3609	.3026
BARS/MEAS	.01083	.01264	.01446	.01808	.02535	.02899	.03628	.05460	.11028	.14799	.18617	.22482
MEAS/BAR	92.2994	79.0875	69.1787	55.3063	39.4523	34.4980	27.5620	18.3144	9.0680	6.7573	5.3715	4.4480
DECK/MEAS	.32692	.38128	.43560	.54414	.76080	.86892	1.08473	1.62182	3.23043	4.29479	5.34861	6.39046
MEAS/DECK	3.0589	2.6228	2.2957	1.8378	1.3144	1.1509	.9219	.6166	.3096	.2328	.1870	.1565
MEAS/PSCHT	95.48736	84.45765	73.93835	59.21129	42.38025	37.12050	29.75678	19.93820	10.11824	7.66263	6.18883	5.20595

SURVIVABLE JUPITER PROBE TASK 3 DESCENT RUNS
JPL MONOGRAPH JUPITER COOL/DENSE ATMOSPHERE
BALLISTIC COEFFICIENT = .090, INITIAL TIME = 0. SECONDS AT 71454.000 KM RADIUS

BAL. COEFS 0.69/0.09/1.50 SEP 10 BARS

RADIUS 71418.000 KM ALTITUDE -4.000 KM PRESSURE 1.264242 BARS TEMPERATURE 153.505 KELVIN
-13.123 KFT 1.247710 ATM -183.361 FAHRENHEIT
TIME 432.335 SEC VELOCITY 53.431 METER/SEC DYN P .003818 BARS
7.20559 MIN 3.8590 MB/SEC DOPPLER 3.873966E+02 CPS
.120093 HRS 175.297 FT/SEC MACH NO .063453

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	145.11	124.52	109.08	87.47	62.76	55.04	44.23	29.82	15.41	11.81	9.65	8.21
KM/MEAS	.16081	.18662	.21322	.26636	.37247	.42543	.53117	.79444	1.97532	2.08868	2.59649	3.09892
MEAS/KM	6.2197	5.3585	4.6900	3.7542	2.6848	2.3505	1.8826	1.2587	.6348	.4788	.3851	.3227
BARS/MEAS	.01160	.01353	.01547	.01935	.02712	.03102	.03882	.05840	.11742	.15800	.19864	.23973
MEAS/BAR	86.2297	73.8893	64.6340	51.6766	36.8682	32.2407	25.7621	17.1243	8.4875	6.3290	5.0342	4.1713
DEGK/MEAS	.31201	.36391	.41577	.51941	.72632	.82960	1.03578	1.54917	3.07187	4.07293	5.06418	6.04494
MEAS/DEGK	3.2050	2.7479	2.4052	1.9253	1.3768	1.2054	.9655	.6455	.3255	.2455	.1975	.1654
MEAS/PSCHT	109.51451	93.91310	82.21202	65.83047	47.10861	41.25799	33.06704	22.14952	11.92287	8.49153	6.85228	5.75911

RADIUS 71415.000 KM ALTITUDE -7.000 KM PRESSURE 1.455814 BARS TEMPERATURE 159.357 KELVIN
-22.966 KFT 1.476253 ATM -172.828 FAHRENHEIT
TIME 490.359 SEC VELOCITY 50.051 METER/SEC DYN P .003819 BARS
8.17265 MIN 4.1216 MB/SEC DOPPLER 3.628858E+02 CPS
.136211 HRS 164.208 FT/SEC MACH NO .058337

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	164.45	141.10	123.59	99.07	71.05	62.29	50.04	33.69	17.35	13.26	10.81	9.17
KM/MEAS	.14991	.17485	.19978	.24959	.34905	.39870	.49785	.74482	1.47812	1.96083	2.43878	2.91211
MEAS/KM	6.6706	5.7192	5.0056	4.0066	2.8649	2.5081	2.0086	1.3426	.6765	.5100	.4100	.3434
BARS/MEAS	.01238	.01445	.01652	.02066	.02895	.03310	.04142	.06230	.12558	.16832	.21150	.25511
MEAS/BAR	80.7753	69.2174	60.5491	48.4134	34.5441	30.2100	24.1423	16.0521	7.9628	5.9410	4.7282	3.9199
DEGK/MEAS	.29264	.34132	.38997	.48721	.68137	.77829	.97184	1.45393	2.88537	3.82764	4.76063	5.68460
MEAS/DEGK	3.4172	2.9298	2.5643	2.0525	1.4676	1.2849	1.0290	.6878	.3466	.2613	.2101	.1759
MEAS/PSCHT	121.32406	104.03558	91.06921	72.91626	52.16994	45.68667	36.61004	24.50762	12.40419	9.37771	7.56143	6.35026

RADIUS 71412.000 KM ALTITUDE -10.000 KM PRESSURE 1.759118 BARS TEMPERATURE 165.213 KELVIN
-32.808 KFT 1.736114 ATM -162.287 FAHRENHEIT
TIME 562.228 SEC VELOCITY 46.995 METER/SEC DYN P .003819 BARS
9.20380 MIN 4.3900 MB/SEC DOPPLER 3.407384E+02 CPS
.153397 HRS 154.184 FT/SEC MACH NO .053767

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	185.08	158.78	139.06	111.45	79.89	70.03	56.22	37.82	19.41	14.81	12.04	10.20
KM/MEAS	.14078	.16421	.18762	.23441	.32786	.37452	.46770	.69987	1.38990	1.84465	2.29531	2.74198
MEAS/KM	7.1032	6.0899	5.3300	4.2660	3.0501	2.6701	2.1381	1.4288	.7195	.5421	.4357	.3647
BARS/MEAS	.01319	.01539	.01759	.02200	.03082	.03525	.04410	.06631	.13357	.17894	.22474	.27095
MEAS/BAR	75.8473	64.9928	56.8549	45.4619	32.4414	28.3725	22.6761	15.0811	7.4866	5.5884	4.4497	3.6907
DEGK/MEAS	.27481	.32054	.36624	.45758	.64080	.73107	.91297	1.36619	2.71317	3.60086	4.48056	5.35249
MEAS/DEGK	3.6388	3.1198	2.7304	2.1854	1.5605	1.3678	1.0953	.7320	.3686	.2777	.2232	.1868
MEAS/PSCHT	133.91670	114.82928	100.51370	80.47187	57.56683	50.40897	40.38791	27.02628	13.66373	10.32252	8.31744	6.98043

SURVIVABLE JUPITER PROBE TASK 3 DESCENT RUNS
JPL MONOGRAPH JUPITER COOL/DENSE ATMOSPHERE
BALLISTIC COEFFICIENT = .09C, INITIAL TIME = 0. SECONDS AT 71454.000 KM RADIUS

BAL. COEF. 0.6E/0.09/1.50 SEP 10 BARS

RADIUS 71409.000 KM ALTITUDE -13.000 KM PRESSURE 2.057145 BARS TEMPERATURE 171.069 KELVIN
-42.651 KFT 2.030244 ATM -151.745 FAHRENHEIT
TIME 618.046 SEC VELOCITY 44.223 METER/SEC DYN P .003819 BARS
10.30076 MIN 4.6655 MR/SEC DOPPLER 3.206403E+02 CPS
.171679 HRS 145.090 FT/SEC MACH NO .049750

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	207.02	177.58	155.51	124.61	89.29	78.26	62.80	42.20	21.60	16.45	13.36	11.30
KM/MEAS	.13250	.15454	.17658	.22067	.30861	.35255	.44030	.66002	1.30959	1.73876	2.16440	2.58659
MEAS/KM	7.5474	6.4707	5.6631	4.5324	3.2403	2.8365	2.2712	1.5154	.7636	.5751	.4620	.3866
BARS/MEAS	.01401	.01635	.01869	.02337	.03275	.03745	.04685	.07043	.14178	.16986	.23835	.28725
MEAS/BAR	71.3672	61.1584	53.5019	42.7827	30.5322	26.7039	21.3444	14.1985	7.0530	5.2669	4.1955	3.4813
DECK/MEAS	.28864	.30168	.34470	.43069	.60243	.68819	.85994	1.28644	2.55639	3.39416	4.22503	5.04917
MEAS/DECK	3.4664	3.3148	2.9011	2.3219	1.6599	1.4531	1.1630	.7773	.3912	.2946	.2367	.1981
MEAS/PSCHT	147.31217	126.31112	110.56032	88.50917	63.30779	55.43232	44.40662	29.70549	15.00351	11.32750	9.12157	7.65068

RADIUS 71406.000 KM ALTITUDE -16.000 KM PRESSURE 2.393053 BARS TEMPERATURE 176.925 KELVIN
-52.493 KFT 2.361760 ATM -141.204 FAHRENHEIT
TIME 647.917 SEC VELOCITY 41.700 METER/SEC DYN P .003819 BARS
11.46529 MIN 4.9483 MR/SEC DOPPLER 3.023443E+02 CPS
.191088 HRS 136.811 FT/SEC MACH NO .046128

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	230.31	197.55	172.98	138.58	99.27	87.99	69.79	46.86	23.93	18.20	14.76	12.47
KM/MEAS	.12495	.14575	.16653	.20808	.29108	.33253	.41534	.62177	1.23626	1.64198	2.04465	2.44431
MEAS/KM	8.0032	6.8613	6.0048	4.8058	3.4354	3.0072	2.4077	1.6083	.8089	.6090	.4891	.4091
BARS/MEAS	.01486	.01734	.01982	.02479	.03473	.03971	.04967	.07466	.15022	.20108	.25234	.30399
MEAS/BAR	67.2915	57.6668	50.4483	40.3425	28.7930	25.1837	20.1309	13.3938	6.6571	4.9731	3.9629	3.2895
DECK/MEAS	.24391	.28450	.32508	.40619	.56821	.64912	.81076	1.21373	2.41324	3.20524	3.99126	4.77143
MEAS/DECK	4.0999	3.5149	3.0762	2.4619	1.7599	1.5405	1.2334	.8239	.4144	.3120	.2505	.2096
MEAS/PSCHT	161.53157	138.49918	121.22488	97.04083	69.40185	60.76464	48.67250	32.54548	16.42566	12.39423	9.97508	8.36207

RADIUS 71403.000 KM ALTITUDE -19.000 KM PRESSURE 2.720166 BARS TEMPERATURE 182.782 KELVIN
-62.336 KFT 2.733942 ATM -130.663 FAHRENHEIT
TIME 761.945 SEC VELOCITY 39.396 METER/SEC DYN P .003819 BARS
12.69909 MIN 5.2381 MR/SEC DOPPLER 2.856369E+02 CPS
.211651 HRS 129.251 FT/SEC MACH NO .042875

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	254.98	218.70	191.49	153.19	109.85	96.24	77.19	51.80	26.40	20.05	16.24	13.70
KM/MEAS	.11806	.13771	.15736	.19662	.27506	.31424	.39282	.58771	1.16911	1.55329	1.93480	2.31370
MEAS/KM	8.4705	7.2617	6.3552	5.0860	3.6355	3.1822	2.5456	1.7015	.8554	.6438	.5168	.4322
BARS/MEAS	.01573	.01836	.02098	.02624	.03676	.04203	.05257	.07900	.15887	.21259	.26670	.32119
MEAS/BAR	63.5689	54.4776	47.6591	38.1133	27.2038	23.7946	19.0217	12.6590	6.2945	4.7039	3.7496	3.1135
DECK/MEAS	.23045	.26981	.30716	.38381	.53694	.61342	.76622	1.14724	2.28216	3.03211	3.77528	4.51237
MEAS/DECK	4.3393	3.7201	3.2556	2.6055	1.8624	1.6302	1.3051	.8717	.4382	.3298	.2649	.2216
MEAS/PSCHT	176.59284	151.41142	132.52309	106.07941	75.95800	66.41378	53.19183	35.56240	17.93227	13.52430	10.87926	9.11568

SURVIVABLE JUPITER PROBE TASK 3 DESCENT RUNS
JPL MONOGRAPH JUPITER COOL/DENSE ATMOSPHERE
BALLISTIC COEFFICIENT = .090, INITIAL TIME = 0. SECONDS AT 71454.000 KM RADIUS

BAL. COEF. 0.65/0.09/1.50 SEP 10 BARS

RADIUS 71400.000 KM ALTITUDE -22.000 KM PRESSURE 3.191084 BARS TEMPERATURE 188.629 KELVIN
-72.178 KFT 3.150244 ATM -120.138 FAHRENHEIT
TIME 840.274 SEC VELOCITY 37.284 METER/SEC DYN P .003823 BARS
14.00379 MIN 5.5397 MB/SEC DOPPLER 2.703294E+02 CPS
.233398 HRS 122.324 FT/SEC MACH NO .039944

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	281.00	241.07	211.06	169.05	121.03	105.03	85.02	57.02	29.01	22.01	17.00	15.00
KM/MEAS	.11174	.13034	.14894	.18611	.26038	.29747	.37159	.55646	1.10742	1.47175	1.83375	2.19345
MEAS/KM	8.9493	7.6721	6.7143	5.3732	3.8406	3.3616	2.6911	1.7971	.9030	.6795	.5453	.4559
BARS/MEAS	.01662	.01940	.02217	.02772	.03884	.04440	.05554	.08345	.16774	.22440	.28143	.33883
MEAS/BAR	60.1575	51.5548	45.1029	36.0701	25.7470	22.5211	18.0047	11.9830	5.9615	4.4563	3.5532	2.9513
DECK/MEAS	.21738	.25357	.28974	.36205	.50654	.57870	.72299	1.08254	2.15437	2.86313	3.56736	4.26712
MEAS/DECK	4.6003	3.9437	3.4514	2.7620	1.9742	1.7280	1.3833	.9238	.4642	.3493	.2803	.2343
MEAS/PSCHT	192.52126	165.06175	144.46711	115.63460	82.68310	72.38573	57.99937	38.74741	19.52480	14.71875	11.83487	9.91207

RADIUS 71397.000 KM ALTITUDE -25.000 KM PRESSURE 3.662215 BARS TEMPERATURE 194.465 KELVIN
-82.021 KFT 3.614328 ATM -109.633 FAHRENHEIT
TIME 922.886 SEC VELOCITY 35.344 METER/SEC DYN P .003823 BARS
15.38144 MIN 5.8443 MB/SEC DOPPLER 2.562634E+02 CPS
.256357 HRS 115.959 FT/SEC MACH NO .037297

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	308.63	264.68	231.72	185.58	132.84	116.36	93.29	62.53	31.76	24.07	19.46	16.38
KM/MEAS	.10993	.12857	.14120	.17645	.24688	.28206	.35235	.52772	1.05063	1.39663	1.74059	2.08253
MEAS/KM	9.4398	8.0925	7.0820	5.6674	4.0516	3.5454	2.8381	1.8949	.9518	.7160	.5745	.4802
BARS/MEAS	.01754	.02046	.02339	.02925	.04097	.04684	.05858	.08801	.17694	.23651	.29654	.35693
MEAS/BAR	57.0224	48.8687	42.7535	34.1922	24.4079	21.3503	17.0656	11.3622	5.6549	4.2282	3.3723	2.8017
DECK/MEAS	.20508	.24039	.27469	.34326	.48027	.54871	.68547	1.02662	2.04390	2.71700	3.38613	4.05134
MEAS/DECK	4.8524	4.1598	3.6404	2.9132	2.0822	1.8225	1.4589	.9741	.4893	.3681	.2953	.2468
MEAS/PSCHT	209.32778	179.46735	157.07201	125.71852	89.88591	78.68820	63.01127	42.10878	21.20560	15.97943	12.84350	10.75269

RADIUS 71394.000 KM ALTITUDE -28.000 KM PRESSURE 4.184724 BARS TEMPERATURE 200.301 KELVIN
-91.864 KFT 4.130001 ATM -99.128 FAHRENHEIT
TIME 1010.007 SEC VELOCITY 33.558 METER/SEC DYN P .003823 BARS
16.83345 MIN 6.1559 MB/SEC DOPPLER 2.433125E+02 CPS
.280557 HRS 110.099 FT/SEC MACH NO .034888

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	337.67	289.57	253.50	203.00	145.29	127.25	102.00	68.33	34.67	26.25	21.20	17.83
KM/MEAS	.10059	.11734	.13408	.16755	.23444	.26785	.33463	.50123	.99825	1.32730	1.65455	1.98002
MEAS/KM	9.9415	8.5225	7.4583	5.9683	4.2655	3.7334	2.9884	1.9951	1.0018	.7534	.6044	.5050
BARS/MEAS	.01847	.02155	.02464	.03080	.04315	.04933	.06170	.09268	.18615	.24990	.31200	.37545
MEAS/BAR	54.1354	46.3952	40.5900	32.4627	23.1744	20.2718	16.2082	10.7901	5.3721	4.0177	3.2051	2.6634
DECK/MEAS	.19569	.22827	.26084	.32595	.45608	.52108	.65095	.97509	1.94198	2.59211	3.21874	3.85192
MEAS/DECK	5.1103	4.3809	3.8338	3.0679	2.1926	1.9191	1.5361	1.0255	.5149	.3873	.3107	.2596
MEAS/PSCHT	227.04148	194.65052	170.35729	136.34675	97.47752	85.33086	68.32551	45.65158	22.97709	17.30813	13.90654	11.63863

SURVIVABLE JUPITER PROBE TASK 3 DESCENT RUNS
JPL MONOGRAPH JUPITER COOL/DENSE ATMOSPHERE
BALLISTIC COEFFICIENT = .090, INITIAL TIME = 0. SECONDS AT 71454.000 KM RADIUS

BAL. COEF. 0.65/0.09/1.50 SEP 10 BARS

RADIUS 71391.000 KM		ALTITUDE	-31.000 KM		PRESSURE	4.763551 BARS		TEMPERATURE	206.138 KELVIN			
			-101.706 KFT			4.701255 ATM			-88.622 FAHRENHEIT			
TIME	1181.696 SEC	VELOCITY	31.910 METER/SEC		DYN P	.003823 BARS						
	18.36159 MIN		6.4745 MI/SEC		DOPPLER	2.313594E+02 CPS						
	.306027 HRS		104.690 FT/SEC		MACH NO	.032701						

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	369.23	315.77	276.42	221.34	158.39	138.71	111.17	74.45	37.72	28.54	23.03	19.36
KM/MEAS	.09565	.11188	.12750	.15934	.22296	.25474	.31828	.47676	.94981	1.26315	1.57491	1.88510
MEAS/KM	10.4545	8.9621	7.8429	6.2760	4.4852	3.9256	3.1421	2.0975	1.0528	.7917	.6350	.5305
BARS/MEAS	.01043	.02267	.02691	.03240	.04538	.05188	.06498	.09745	.19567	.25158	.32783	.39441
MEAS/BAR	51.4707	44.1119	38.5928	30.8661	22.0356	19.2760	15.4127	10.2616	5.1106	3.8230	3.0504	2.5354
DECK/MEAS	.19608	.21707	.24804	.30997	.43374	.49557	.61913	.92749	1.84775	2.45733	3.06382	3.66726
MEAS/DECK	5.3740	4.6069	4.0315	3.2261	2.3056	2.0179	1.6152	1.0782	.5412	.4069	.3264	.2727
MEAS/PSCHT	245.69290210.628791		184.3382	147.5315105.66667		92.32138	73.91793	49.37989	24.84134	18.70638	15.02521	12.57093

RADIUS 71398.000 KM		ALTITUDE	-34.000 KM		PRESSURE	5.402920 BARS		TEMPERATURE	211.974 KELVIN			
			-111.549 KFT			5.332267 ATM			-78.117 FAHRENHEIT			
TIME	1198.053 SEC	VELOCITY	30.385 METER/SEC		DYN P	.003823 BARS						
	19.96755 MIN		6.8000 MI/SEC		DOPPLER	2.203023E+02 CPS						
	.332793 HRS		99.697 FT/SEC		MACH NO	.030707						

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	408.35	343.30	300.51	240.61	172.16	150.76	120.81	80.87	40.94	30.99	24.96	20.97
KM/MEAS	.09109	.10626	.12142	.15174	.21233	.24260	.30311	.45411	.90494	1.20370	1.50106	1.79702
MEAS/KM	10.9785	9.4113	8.2359	6.5903	4.7097	4.1220	3.2992	2.2021	1.1051	.8308	.6662	.5565
BARS/MEAS	.02041	.02331	.02721	.03403	.04766	.05448	.06814	.10233	.20541	.27454	.34401	.41380
MEAS/BAR	49.0054	41.9995	36.7451	29.3889	20.9818	18.3546	14.6795	9.7724	4.8694	3.6424	2.9069	2.4166
DECK/MEAS	.17720	.20671	.23621	.29519	.41306	.47196	.58966	.88342	1.76046	2.34167	2.92014	3.49592
MEAS/DECK	5.6433	4.8377	4.2335	3.3877	2.4209	2.1188	1.6959	1.1320	.5680	.4270	.3424	.2860
MEAS/PSCHT	285.27202227.41956199.03020159.28509113.96207						99.66735	79.79473	53.29778	26.80036	20.17571	16.20074 13.55060

RADIUS 71385.000 KM		ALTITUDE	-37.000 KM		PRESSURE	6.107240 BARS		TEMPERATURE	217.810 KELVIN			
			-121.391 KFT			6.027377 ATM			-67.612 FAHRENHEIT			
TIME	1299.180 SEC	VELOCITY	28.971 METER/SEC		DYN P	.003823 BARS						
	21.65299 MIN		7.1324 MI/SEC		DOPPLER	2.100520E+02 CPS						
	.360883 HRS		95.049 FT/SEC		MACH NO	.028883						

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	434.06	372.19	325.79	260.84	186.60	163.40	130.92	87.61	44.31	33.48	26.98	22.65
KM/MEAS	.08685	.10132	.11578	.14469	.20247	.23135	.28909	.43309	.86328	1.14848	1.43244	1.71515
MEAS/KM	11.5137	9.8700	8.6372	6.9113	4.9389	4.3225	3.4596	2.3090	1.1584	.8707	.6981	.5830
BARS/MEAS	.02140	.02497	.02855	.03569	.04996	.05714	.07146	.10731	.21535	.28779	.36054	.43362
MEAS/BAR	46.7199	40.0411	35.0320	28.0192	20.0046	17.5001	13.9937	9.3196	4.6435	3.4748	2.7736	2.3062
DECK/MEAS	.16896	.19710	.22523	.28148	.39389	.45006	.56232	.84253	1.67941	2.23425	2.78665	3.33665
MEAS/DECK	5.9184	5.0735	4.4398	3.5527	2.5388	2.2219	1.7783	1.1869	.5954	.4476	.3589	.2997
MEAS/PSCHT	285.82932245.04010214.44018171.61947122.67235107.37635						85.96193	57.40927	28.85618	21.71763	17.43433	14.57865

SURVIVABLE JUPITER PROBE TASK 3 DESCENT RUNS
JPL MONOGRAPH JUPITER COOL/DENSE ATMOSPHERE
BALLISTIC COEFFICIENT = .090, INITIAL TIME = 0. SECONDS AT 71454.000 KM RADIUS

BAL. COEF. 0.65/0.09/1.50 SEP 10 BARS

RADIUS 71382.000 KM ALTITUDE -40.000 KM PRESSURE 6.881111 BARS TEMPERATURE 223.646 KELVIN
-131.234 KFT 6.791128 ATM -57.107 FAHRENHEIT
TIME 1405.174 SEC VELOCITY 27.658 METER/SEC DYN P .003823 BARS
23.41956 MIN 7.4717 MB/SEC DOPPLER 2.005304E+02 CPS
.390326 HRS 90.740 FT/SEC MACH NO .027212

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	469.39	402.48	352.29	282.03	281.74	176.65	141.52	94.68	47.84	36.13	29.10	24.42
KM/MEAS	.08292	.09673	.11054	.13814	.19332	.22089	.27599	.41356	.82453	1.09710	1.36856	1.63892
MEAS/KM	12.0598	10.3380	9.0467	7.2389	5.1728	4.5272	3.6233	2.4180	1.2128	.9115	.7307	.6102
BARS/MEAS	.02242	.02616	.02990	.03739	.05236	.05986	.07485	.11240	.22551	.30131	.37743	.45386
MEAS/BAR	44.5967	38.2217	33.4405	26.7467	19.0967	16.7061	13.3592	8.8968	4.4344	3.3188	2.6495	2.2033
DECK/MEAS	.16131	.18818	.21504	.26974	.37608	.42971	.53692	.80453	1.60404	2.13430	2.66239	3.18834
MEAS/DECK	6.1991	5.3141	4.6503	3.7211	2.6590	2.3271	1.8625	1.2430	.6234	.4685	.3756	.3136
MEAS/PSCHT	307.37470263.50757230.60722184.54671131.90609115.45588								92.42557	61.71639	31.01079	23.33364	18.72719	15.65609

RADIUS 71379.000 KM ALTITUDE -43.000 KM PRESSURE 7.229324 BARS TEMPERATURE 229.482 KELVIN
-141.075 KFT 7.628250 ATM -46.602 FAHRENHEIT
TIME 1516.134 SEC VELOCITY 26.435 METER/SEC DYN P .003823 BARS
25.26890 MIN 7.8179 MB/SEC DOPPLER 1.916666E+02 CPS
.421148 HRS 86.730 FT/SEC MACH NO .025676

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	506.38	434.18	380.03	304.23	217.59	190.52	152.61	102.08	51.54	38.90	31.32	26.27
KM/MEAS	.07926	.09246	.10566	.13205	.18479	.21115	.26384	.39537	.78843	1.04921	1.30900	1.56780
MEAS/KM	12.6168	10.8155	9.4645	7.5731	5.4115	4.7359	3.7902	2.5293	1.2683	.9531	.7639	.6378
BARS/MEAS	.02346	.02738	.03129	.03912	.05479	.06263	.07832	.11750	.23568	.31512	.39466	.47452
MEAS/BAR	42.6206	36.5283	31.9591	25.5623	18.2516	15.9670	12.7666	8.5040	4.2395	3.1734	2.5338	2.1074
DECK/MEAS	.15419	.17987	.20555	.25688	.35950	.41077	.51326	.76914	1.53381	2.04113	2.54652	3.04999
MEAS/DECK	6.4855	5.5595	4.8651	3.8928	2.7817	2.4344	1.9483	1.3001	.6520	.4899	.3927	.3279
MEAS/PSCHT	329.92808282.83904247.52225198.07874141.57183123.91341								99.19160	66.22909	33.26620	25.02524	20.06052	16.78391

RADIUS 71376.000 KM ALTITUDE -46.000 KM PRESSURE 8.656867 BARS TEMPERATURE 235.318 KELVIN
-150.919 KFT 8.543663 ATM -36.097 FAHRENHEIT
TIME 1632.158 SEC VELOCITY 25.296 METER/SEC DYN P .003823 BARS
27.20264 MIN 8.1708 MB/SEC DOPPLER 1.834059E+02 CPS
.453377 HRS 82.991 FT/SEC MACH NO .024263

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	545.85	467.33	409.04	327.43	234.17	205.02	164.22	109.61	55.41	41.80	33.64	28.20
KM/MEAS	.07585	.08848	.10111	.12636	.17684	.20207	.25249	.37840	.75473	1.00450	1.25337	1.50136
MEAS/KM	13.1847	11.3022	9.8903	7.9137	5.6547	4.9488	3.9605	2.6427	1.3250	.9955	.7978	.6661
BARS/MEAS	.02452	.02861	.03270	.04089	.05726	.06545	.08185	.12280	.24645	.32920	.41224	.49559
MEAS/BAR	40.7780	34.9493	30.5779	24.4623	17.4634	15.2777	12.2217	8.1376	4.0577	3.0377	2.4257	2.0178
DECK/MEAS	.14755	.17212	.19670	.24583	.34403	.39310	.49120	.73613	1.46825	1.95414	2.43830	2.92074
MEAS/DECK	6.7774	5.8097	5.0846	4.0679	2.9067	2.5439	2.0358	1.3585	.6811	.5117	.4101	.3424
MEAS/PSCHT	353.50922303.05144265.20811218.22742151.67884132.75635106.28595								70.94534	35.62438	26.79392	21.49550	17.96310

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SURVIVABLE JUPITER PROBE TASK 3 DESCENT RUNS
  JPL MONOGRAPH JUPITER COOL/DENSE ATMOSPHERE
BALLISTIC COEFFICIENT =   .090,  INITIAL TIME =     0.   SECONDS AT 71454.000 KM RADIUS

 BAL. COEF.  0.65/0.09/1.50          SEE 10 BARS

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RADIUS 71373.000 KM      ALTITUDE  -49.000 KM            PRESSURE     9.668924 BARS      TEMPERATURE  241.155 KELVIN
                                  -160.761 KFT                        9.542486 ATM                    -25.592 FAHRENHEIT
  TIME  1753.344 SEC     VELOCITY   24.231 METER/SEC       DYN P      .003823 BARS
        29.22240 MIN                 8.5304 MP/SEC       DOPPLER    1.758861E+02 CPS
         .487040 HRS                 79.499 FT/SEC       MACH NO     .022959

INSTRUMENTS      TEMP     PRESS      TEMP     PRESS     ACCEL     ACCEL     ACCEL     ACCEL     M SPEC    M SPEC    M SPEC    M SPEC
NO OF MEAS     585.45    501.96    439.34    351.67    251.48    220.17    176.33    117.89     59.44     44.83     36.07     30.22
KM/MEAS         .07266    .08476    .09686    .12105    .13942    .19359    .24190    .36254    .72323    .96268   1.20133   1.43919
MEAS/KM       13.7634   11.7982   10.3243    8.2609    5.9026    5.1657    4.1340    2.7583    1.3827    1.0388     .8324     .6948
BARS/MEAS       .02560    .02987    .03414    .04269    .05978    .06834    .08548    .12820    .25722    .34355    .43017    .51708
MEAS/BAR      39.0569   33.4744   29.2876   23.4261   16.7272   14.6338   11.7030    7.7953    3.8877    2.9108    2.3247    1.9339
DEGK/MEAS       .14135    .16489    .18843    .23549    .32958    .37660    .47065    .70598   1.40697   1.87279   2.33784   2.80150
MEAS/DEGK      7.0749    6.0647    5.3071    4.2464    3.0342    2.6553    2.1250    1.4170     .7107     .5340     .4277     .3570
MEAS/PSCHT 378.13777324.16163283.67952227.00456162.23314141.99206113.69453 75.87108 38.08729 28.64114 22.97330 19.19464

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RADIUS 71372.000 KM      ALTITUDE  -50.000 KM            PRESSURE    10.025982 BARS      TEMPERATURE  243.100 KELVIN
                                  -164.042 KFT                        9.894875 ATM                    -22.090 FAHRENHEIT
  TIME  1734.906 SEC     VELOCITY   23.892 METER/SEC       DYN P      .003824 BARS
        28.91510 MIN                 8.6551 MP/SEC       DOPPLER    1.732283E+02 CPS
         .499595 HRS                 78.386 FT/SEC       MACH NO     .022647

INSTRUMENTS      TEMP     PRESS      TEMP     PRESS     ACCEL     ACCEL     ACCEL     ACCEL     M SPEC    M SPEC    M SPEC    M SPEC
NO OF MEAS     596.30    513.83    449.73    359.98    257.42    225.36    180.49    120.66     60.83     45.87     36.90     30.92
KM/MEAS         .07164    .08357    .09550    .11936    .13705    .19088    .23852    .35748     .71319    .94935   1.18473   1.41936
MEAS/KM       13.9587   11.9656   10.4708    8.3780    5.9863    5.2389    4.1929    2.7973    1.4022    1.0534     .8441     .7045
BARS/MEAS       .02597    .03030    .03463    .04330    .06063    .06931    .08666    .13010    .26086    .34840    .43622    .52433
MEAS/BAR      38.5083   33.0044   28.8764   23.0972   16.4925   14.4285   11.5389    7.6862    3.8335    2.8703    2.2924    1.9072
DEGK/MEAS       .13965    .16291    .18616    .23267    .32562    .37209    .46454    .69883   1.39020   1.85054   2.30937   2.76672
MEAS/DEGK      7.1610    6.1385    5.3716    4.2980    3.0710    2.6876    2.1528    1.4311     .7193     .5404     .4330     .3614
MEAS/PSCHT 386.58354331.40088290.01388232.07206165.85282145.15630116.18834 77.56033 38.93198 29.27469 23.48019 19.61709

BALLISTIC COEFFICIENT CHANGED FROM  .090 TO 1.500


ADDITIONAL BIT RATES REQUIRED TO READ OUT ENTRY DATA
ONCE      3.788
TWICE     7.577
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SURVIVABLE JUPITER PROBE TASK 3 DESCENT RUNS
JPL MONOGRAPH JUPITER COOL/DENSE ATMOSPHERE
BALLISTIC COEFFICIENT = 1.500, INITIAL TIME = 1756.01 SECONDS AT 71372.000 KM RADIUS

BAL. COEF. 0.66/0.99/1.50 SEE 10 BARS

SAMPLE INTERVALS (SECONDS)

TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
3.000	3.500	4.000	5.000	7.000	8.000	10.000	15.000	30.000	40.000	50.000	60.000

BITS PER SAMPLE

TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
10.000	10.000	10.000	10.000	30.000	30.000	30.000	30.000	400.000	400.000	400.000	400.000

NO OF PREVIOUS MEASUREMENTS

TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
589.302	513.830	449.726	359.081	257.415	225.363	180.491	120.660	60.830	45.873	36.898	30.915

REQUIRED BIT RATE = 61.7262 BITS/SECOND

ENTRY DATA IN STORAGE = 6800.0 BITS

SURVIVABLE JUPITER PROBE TASK 3 DESCENT RUNS
JPL MONOGRAPH JUPITER COOL/DENSE ATMOSPHERE
BALLISTIC COEFFICIENT = 1.500, INITIAL TIME = 1794.91 SECONDS AT 71372.000 KM RADIUS

BAL. COEF. 0.65/0.09/1.50 SEE 10 BARS

RADIUS 71372.000 KM	ALTITUDE	-50.000 KM		PRESSURE	10.025582 BARS		TEMPERATURE	243.100 KELVIN				
		-164.042 KFT			9.894875 ATM			-22.050 FAHRENHEIT				
TIME 1794.906 SEC	VELOCITY	97.539 METER/SEC		DYN P	.063734 BARS							
29.91510 MIN		36.3744 MP/SEC		DOPPLER	7.072014E+02 CPS							
.4985E5 HRS		320.009 FT/SEC		MACH NO	.092047							

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	600.30	514.83	450.73	360.98	258.42	225.36	181.49	121.66	61.83	46.87	37.90	31.92
KM/MEAS	.29202	.34057	.38009	.48603	.67053	.77608	.98875	1.44833	2.86927	3.79989	4.72002	5.62906
MEAS/KM	3.4245	2.9362	2.6701	2.0575	1.4716	1.2885	1.0322	.6904	.3486	.2632	.2119	.1776
BARS/MEAS	.10618	.12392	.14167	.17721	.24843	.28412	.35563	.53926	1.08137	1.45145	1.82632	2.20597
MEAS/BAR	9.4179	8.0698	7.0596	5.6430	4.0252	3.5197	2.8119	1.8547	.9248	.6890	.5475	.4533
DEGK/MEAS	.59922	.66387	.75845	.94741	1.32458	1.51279	1.88844	2.82320	5.59105	7.40703	9.20062	10.97259
MEAS/DEGK	1.7568	1.5067	1.3185	1.0555	.7550	.6610	.5295	.3542	.1789	.1350	.1087	.0911
MEAS/PSCHT	94.92324	81.40624	71.26847	57.07556	40.85497	35.78559	28.68934	19.22687	9.76303	7.39630	5.97577	5.02836

RADIUS 71369.000 KM	ALTITUDE	-53.000 KM		PRESSURE	11.151168 BARS		TEMPERATURE	248.948 KELVIN				
		-173.885 KFT			11.013184 ATM			-11.564 FAHRENHEIT				
TIME 1826.312 SEC	VELOCITY	93.563 METER/SEC		DYN P	.063734 BARS							
30.43854 MIN		36.8388 MP/SEC		DOPPLER	6.783782E+02 CPS							
.507309 HRS		306.967 FT/SEC		MACH NO	.088252							

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	610.77	523.80	458.58	367.26	262.90	230.29	184.63	123.75	62.88	47.66	38.53	32.44
KM/MEAS	.29015	.33674	.37330	.46632	.65203	.74470	.92970	1.39018	2.75475	3.65090	4.53662	5.41226
MEAS/KM	3.5695	3.0505	2.6788	2.1444	1.5337	1.3428	1.0756	.7193	.3630	.2739	.2204	.1848
BARS/MEAS	.11079	.12919	.14769	.18473	.25895	.29614	.37054	.55774	1.12698	1.51084	1.90029	2.29441
MEAS/BAR	9.0337	7.7407	6.7710	5.4137	3.8617	3.3768	2.6980	1.7930	.8870	.6619	.5262	.4358
DEGK/MEAS	.54609	.63690	.72766	.90900	1.27098	1.45163	1.81224	2.70984	5.36977	7.11660	8.84311	10.54998
MEAS/DEGK	1.8312	1.5701	1.3743	1.1001	.7868	.6889	.5518	.3690	.1862	.1405	.1131	.0948
MEAS/PSCHT	101.30775	86.87868	76.05697	60.90629	43.59123	38.18023	30.60476	20.50384	10.40171	7.87544	6.35922	5.34804

RADIUS 71366.000 KM	ALTITUDE	-56.000 KM		PRESSURE	12.389567 BARS		TEMPERATURE	254.796 KELVIN				
		-183.727 KFT			12.227552 ATM			-1.038 FAHRENHEIT				
TIME 1859.037 SEC	VELOCITY	89.837 METER/SEC		DYN P	.063734 BARS							
30.98396 MIN		38.3703 MP/SEC		DOPPLER	6.513562E+02 CPS							
.516399 HRS		294.739 FT/SEC		MACH NO	.082810							

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	621.68	533.15	466.76	373.81	267.58	234.38	187.90	125.94	63.97	48.48	39.18	32.98
KM/MEAS	.28982	.31377	.35848	.44784	.62623	.71526	.89302	1.33558	2.64801	3.51067	4.36385	5.20786
MEAS/KM	3.7171	3.1871	2.7895	2.2330	1.5965	1.3981	1.1198	.7487	.3776	.2848	.2292	.1920
BARS/MEAS	.11529	.13455	.15382	.19239	.26967	.30838	.38593	.58063	1.17163	1.57137	1.97569	2.38457
MEAS/BAR	8.6735	7.4322	6.5012	5.1978	3.7083	3.2428	2.5911	1.7223	.8535	.6364	.5062	.4194
DEGK/MEAS	.52440	.61162	.69878	.87236	1.22069	1.39424	1.74073	2.60341	5.16171	6.84326	8.50635	10.15156
MEAS/DEGK	1.9069	1.6350	1.4311	1.1455	.8192	.7172	.5745	.3841	.1937	.1461	.1176	.0985
MEAS/PSCHT	107.99987	92.58051	81.04597	64.89758	46.44218	40.67482	32.60045	21.93436	11.06713	8.37463	6.75870	5.68106

SURVIVABLE JUPITER PROBE TASK 3 DESCENT RUNS
JPL MONOGRAPH JUPITER COOL/DENSE ATMOSPHERE
BALLISTIC COEFFICIENT = 1.500, INITIAL TIME = 1794.91 SECONDS AT 71372.000 KM RADIUS

BAL. COEF. 0.65/0.09/1.50 SEP 10 BARS

RADIUS 71363.000 KM		ALTITUDE	-59.000 KM		PRESSURE	13.723207 BARS		TEMPERATURE	260.643 KELVIN			
			-193.570 KFT			13.543757 ATM			9.488 FAHRENHEIT			
TIME	1493.104 SEC	VELOCITY	86.337 METER/SEC		DYN P	.063734 BARS						
	31.55174 MIN		39.9287 MPH/SEC		DOPPLER	6.259868E+02 CPS						
	.525862 HRS		283.259 FT/SEC		MACH NO	.07868						

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	633.03	542.89	475.28	390.62	272.44	238.64	191.31	128.21	65.10	49.33	39.86	33.55
KM/MEAS	.25867	.30158	.34457	.43047	.60199	.68760	.85854	1.28424	2.54752	3.37854	4.20093	5.01495
MEAS/KM	3.8674	3.3158	2.9022	2.3230	1.6612	1.4543	1.1648	.7787	.3925	.2960	.2380	.1994
BARS/MEAS	.11997	.14001	.16006	.20018	.28057	.32083	.40115	.60394	1.21802	1.63302	2.05250	2.47645
MEAS/BAR	8.3352	7.1424	6.2478	4.9954	3.5641	3.1169	2.4917	1.6558	.8210	.6124	.4872	.4038
DEGK/MEAS	.50403	.58787	.67166	.83911	1.17344	1.34022	1.67383	2.50334	4.96582	6.58570	8.18078	9.77391
MEAS/DEGK	1.9840	1.7011	1.4888	1.1917	.8522	.7461	.5975	.3995	.2014	.1518	.1221	.1023
MEAS/PSCHT	114.88431	98.51674	86.23931	69.05226	49.40983	43.27157	34.67784	23.21934	11.75976	8.89422	7.17448	6.02767

RADIUS 71360.000 KM		ALTITUDE	-62.000 KM		PRESSURE	15.166085 BARS		TEMPERATURE	266.491 KELVIN			
			-203.412 KFT			14.967766 ATM			20.014 FAHRENHEIT			
TIME	1528.536 SEC	VELOCITY	83.047 METER/SEC		DYN P	.063734 BARS						
	32.14227 MIN		41.5140 MPH/SEC		DOPPLER	6.021322E+02 CPS						
	.535705 HRS		272.465 FT/SEC		MACH NO	.07485?						

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	644.85	553.01	484.13	397.71	277.51	243.07	194.85	130.57	66.28	50.21	40.57	34.14
KM/MEAS	.24875	.29013	.33149	.41414	.57918	.66157	.82610	1.23891	2.45279	3.25386	4.04707	4.83263
MEAS/KM	4.0202	3.4468	3.0167	2.4147	1.7266	1.5116	1.2105	.8071	.4077	.3073	.2471	.2069
BARS/MEAS	.12474	.14556	.16640	.20811	.29167	.33351	.41737	.62766	1.26523	1.69579	2.13073	2.57005
MEAS/BAR	8.0170	6.8699	6.0095	4.8051	3.4286	2.9984	2.3962	1.5932	.7904	.5897	.4693	.3891
DEGK/MEAS	.49447	.56554	.64616	.80727	1.12898	1.28659	1.61029	2.40913	4.77624	6.32172	7.87193	9.39729
MEAS/DEGK	2.0224	1.7682	1.5476	1.2387	.8858	.7774	.6210	.4151	.2094	.1579	.1270	.1064
MEAS/PSCHT	122.0?573104.58840		91.64038	73.37313	52.49618	45.97210	36.83831	24.65970	12.44011	9.43457	7.60685	6.38805

RADIUS 71357.000 KM		ALTITUDE	-65.008 KM		PRESSURE	16.724492 BARS		TEMPERATURE	272.330 KELVIN			
			-213.255 KFT			16.507590 ATM			30.524 FAHRENHEIT			
TIME	1565.357 SEC	VELOCITY	79.949 METER/SEC		DYN P	.063753 BARS						
	32.75594 MIN		43.1392 MPH/SEC		DOPPLER	5.798645E+02 CPS						
	.545932 HRS		262.299 FT/SEC		MACH NO	.071287						

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	657.12	563.53	493.74	395.07	282.77	247.67	198.54	133.02	67.51	51.13	41.31	34.76
KM/MEAS	.23949	.27973	.31915	.39874	.55769	.63704	.79551	1.19032	2.36333	3.13606	3.90161	4.66017
MEAS/KM	4.1756	3.5800	3.1333	2.5079	1.7931	1.5698	1.2571	.8401	.4231	.3189	.2563	.2146
BARS/MEAS	.12958	.15121	.17286	.21618	.30296	.34641	.43345	.65180	1.31333	1.75974	2.21044	2.66544
MEAS/BAR	7.7193	6.6131	5.7850	4.6257	3.3008	2.8867	2.3071	1.5342	.7614	.5683	.4524	.3752
DEGK/MEAS	.46502	.54239	.61972	.77426	1.08289	1.23697	1.54468	2.31131	4.58899	6.08944	7.57594	9.04886
MEAS/DEGK	2.1504	1.8437	1.6136	1.2916	.9235	.8084	.6474	.4327	.2179	.1642	.1320	.1105
MEAS/PSCHT	126.56648111.10044		97.25090	77.96151	55.70212	48.77729	39.08244	26.19576	13.22813	9.95564	8.05578	6.76224

SURVIVABLE JUPITER PROBE TASK 2 DESCENT RUNS
JPL MONOGRAPH JUPITER COOL/DENSE ATMOSPHERE
BALLISTIC COEFFICIENT = 1.500, INITIAL TIME = 1798.91 SECONDS AT 71372.000 KM RADIUS

BAL. COEF. 0.65/0.09/1.50 SEP 10 PARS

RADIUS 71354.000 KM ALTITUDE -68.000 KM PRESSURE 18.405009 BARS TEMPERATURE 278.155 KELVIN
-223.097 KFT 18.164331 ATM 41.010 FAHRENHEIT
TIME 2003.589 SEC VELOCITY 77.025 METER/SEC DYN P .063753 BARS
33.39315 MIN 44.7802 MB/SEC DOPPLER 5.584693E+02 CPS
.556553 HRS 252.708 FT/SEC MACH NO .067954

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	669.86	574.45	502.90	402.72	288.23	252.45	202.36	135.57	68.79	52.09	42.07	35.39
KM/MEAS	.23075	.26914	.30752	.38422	.53740	.61388	.76664	1.14728	2.27878	3.02465	3.76395	4.49685
MEAS/KM	4.3337	3.7155	3.2518	2.6027	1.8608	1.6290	1.3044	.8716	.4388	.3306	.2657	.2224
BARS/MEAS	.13451	.15696	.17943	.22439	.31445	.35954	.44965	.67836	1.36226	1.82480	2.29156	2.76252
MEAS/BAR	7.4345	6.3709	5.5732	4.4565	3.1802	2.7813	2.2230	1.4745	.7341	.5480	.4364	.3620
DECK/MEAS	.44806	.52261	.59713	.74606	1.04350	1.19201	1.48862	2.22773	4.42482	5.87311	7.30865	8.73175
MEAS/DECK	2.2319	1.9135	1.6747	1.3404	.9583	.8389	.6718	.4489	.2260	.1703	.1368	.1145
MEAS/PSCHT	137.33085	117.75544	103.07403	82.52002	59.02965	51.68887	41.41173	27.70866	14.00469	10.57815	8.52188	7.15075

RADIUS 71351.000 KM ALTITUDE -71.000 KM PRESSURE 20.214391 BARS TEMPERATURE 283.961 KELVIN
-232.940 KFT 19.950053 ATM 51.495 FAHRENHEIT
TIME 2043.257 SEC VELOCITY 74.266 METER/SEC DYN P .063753 BARS
34.05429 MIN 46.4479 MB/SEC DOPPLER 5.384632E+02 CPS
.567571 HRS 243.855 FT/SEC MACH NO .064844

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	683.09	585.79	512.81	410.65	293.89	257.41	206.33	138.22	70.11	53.08	42.87	36.05
KM/MEAS	.22250	.25953	.29653	.37050	.51824	.59202	.73937	1.10661	2.19882	2.91922	3.63360	4.34211
MEAS/KM	4.4944	3.8532	3.3723	2.6990	1.9296	1.6891	1.3525	.9037	.4548	.3426	.2752	.2303
BARS/MEAS	.13952	.16281	.18611	.23274	.32613	.37288	.46652	.70134	1.41202	1.89098	2.37407	2.86128
MEAS/BAR	7.1675	6.1422	5.3732	4.2966	3.0663	2.6818	2.1435	1.4258	.7082	.5288	.4212	.3495
DECK/MEAS	.43204	.50393	.57579	.71942	1.00630	1.14955	1.43566	2.14875	4.26954	5.66838	7.05583	8.43198
MEAS/DECK	2.3146	1.9844	1.7367	1.3900	.9937	.8699	.6965	.4654	.2342	.1764	.1417	.1186
MEAS/PSCHT	145.38586	124.65991	109.11544	87.35316	62.48190	54.70960	43.82833	29.31976	14.81035	11.18247	9.00542	7.55378

RADIUS 71348.000 KM ALTITUDE -74.000 KM PRESSURE 22.155589 BARS TEMPERATURE 289.806 KELVIN
-242.782 KFT 21.869814 ATM 61.980 FAHRENHEIT
TIME 2094.384 SEC VELOCITY 71.658 METER/SEC DYN P .063753 BARS
34.73974 MIN 48.1421 MB/SEC DOPPLER 5.199566E+02 CPS
.578996 HRS 235.100 FT/SEC MACH NO .061935

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	696.79	597.54	523.10	418.88	299.77	262.55	210.44	140.96	71.48	54.11	43.69	36.74
KM/MEAS	.21470	.25043	.28615	.35754	.50013	.57134	.71388	1.06814	2.12311	2.81934	3.51005	4.19536
MEAS/KM	4.6576	3.9931	3.4947	2.7969	1.9995	1.7503	1.4014	.9362	.4710	.3547	.2849	.2384
BARS/MEAS	.14481	.16875	.19289	.24122	.33789	.38644	.48346	.72672	1.46259	1.95825	2.45795	2.96170
MEAS/BAR	6.9152	5.9260	5.1842	4.1456	2.9586	2.5877	2.0684	1.3760	.6837	.5107	.4068	.3376
DECK/MEAS	.41696	.48636	.55574	.69439	.97135	1.10966	1.38693	2.07459	4.12367	5.47596	6.81753	8.14863
MEAS/DECK	2.3983	2.0561	1.7994	1.4401	1.0295	.9012	.7215	.4820	.2425	.1826	.1467	.1227
MEAS/PSCHT	153.73672	131.81780	115.37860	92.36369	66.86087	57.84120	46.33363	30.99000	15.64557	11.80897	9.50670	7.97160

SURVIVABLE JUPITER PROBE TASK 3 DESCENT RUNS
JPL MONOGRAPH JUPITER COOL/DENSE ATMOSPHERE
BALLISTIC COEFFICIENT = 1.500, INITIAL TIME = 1794.91 SECONDS AT 71372.000 KM RADIUS

BAL. COEF. 0.65/0.09/1.50 SEP 10 BARS

RADIUS 71345.000 KM ALTITUDE -77.008 KM PRESSURE 24.247770 BARS TEMPERATURE 295.633 KELVIN
-252.625 KFT 23.930689 ATM 72.469 FAHRENHEIT
TIME 2126.992 SEC VELOCITY 69.192 METER/SEC DYN P .063771 BARS
35.44987 MIN 49.8772 MI/SEC DOPPLER 5.016707E+02 CPS
.590831 HRS 227.006 FT/SEC MACH NO .059211

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	711.00	609.71	533.75	427.40	305.86	267.87	214.70	143.80	72.90	55.17	44.54	37.45
KM/MEAS	.20733	.24183	.27632	.34527	.48290	.55177	.68917	1.03171	2.05136	2.72463	3.39283	4.05607
MEAS/KM	4.8233	4.1351	3.6189	2.8963	2.0704	1.8124	1.4510	.9693	.4875	.3670	.2947	.2465
BARS/MEAS	.14078	.17478	.19979	.24983	.35005	.40021	.50067	.75250	1.51398	2.02661	2.54321	3.06378
MEAS/BAR	6.6764	5.7215	5.0053	4.0027	2.8568	2.4987	1.9973	1.3289	.6605	.4934	.3932	.3264
DEGK/MEAS	.40269	.46971	.53671	.67062	.93812	1.07171	1.33857	2.00390	3.98438	5.29207	6.58992	7.87813
MEAS/DEGK	2.4833	2.1290	1.8632	1.4912	1.0660	.9331	.7471	.4990	.2510	.1890	.1517	.1269
MEAS/PSCHT	162.38828	139.23342	121.86727	99.55463	69.76870	61.08556	48.92913	32.72037	16.51084	12.45799	10.02599	8.40441

RADIUS 71342.000 KM ALTITUDE -80.000 KM PRESSURE 26.486329 BARS TEMPERATURE 301.460 KELVIN
-262.467 KFT 26.139974 ATM 82.957 FAHRENHEIT
TIME 2171.104 SEC VELOCITY 66.855 METER/SEC DYN P .063771 BARS
36.18507 MIN 51.6247 MI/SEC DOPPLER 4.847356E+02 CPS
.603085 HRS 219.341 FT/SEC MACH NO .056656

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	725.70	622.32	544.78	436.22	312.16	273.39	219.11	146.74	74.37	56.28	45.42	38.19
KM/MEAS	.20034	.23368	.26702	.33364	.46675	.53323	.66603	.99718	1.98330	2.63474	3.28152	3.92373
MEAS/KM	4.9916	4.2793	3.7451	2.9972	2.1425	1.8754	1.5014	1.0028	.5042	.3795	.3047	.2549
BARS/MEAS	.15503	.18090	.20679	.25858	.36229	.41420	.51814	.77869	1.56618	2.09607	2.62985	3.16752
MEAS/BAR	6.4503	5.5278	4.8359	3.8673	2.7602	2.4143	1.9300	1.2842	.6385	.4771	.3803	.3157
DEGK/MEAS	.38512	.45388	.51963	.64804	.90657	1.03569	1.29364	1.93683	3.85218	5.11748	6.37372	7.62110
MEAS/DEGK	2.5969	2.2032	1.9242	1.5431	1.1031	.9655	.7730	.5163	.2596	.1954	.1569	.1312
MEAS/PSCHT	171.34465	146.91032	128.58455	102.92846	73.60716	64.44422	51.61867	34.51169	17.40659	13.12987	10.56355	8.85245

RADIUS 71339.000 KM ALTITUDE -83.000 KM PRESSURE 28.882891 BARS TEMPERATURE 307.287 KELVIN
-272.310 KFT 28.505197 ATM 93.446 FAHRENHEIT
TIME 2216.743 SEC VELOCITY 64.640 METER/SEC DYN P .063771 BARS
36.94572 MIN 53.3984 MI/SEC DOPPLER 4.686691E+02 CPS
.615762 HRS 212.073 FT/SEC MACH NO .054257

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	740.91	635.36	556.19	445.35	318.68	279.09	223.67	149.78	75.89	57.42	46.33	38.95
KM/MEAS	.19371	.22596	.25819	.32262	.45134	.51764	.64409	.96442	1.91867	2.54935	3.17573	3.79791
MEAS/KM	5.1623	4.4257	3.8731	3.0996	2.2156	1.9323	1.5526	1.0369	.5212	.3923	.3149	.2633
BARS/MEAS	.16035	.18712	.21389	.26746	.37472	.42840	.53580	.80527	1.61920	2.16660	2.71784	3.27289
MEAS/BAR	6.2359	5.3441	4.6752	3.7388	2.6687	2.3343	1.8661	1.2418	.6176	.4616	.3679	.3055
DEGK/MEAS	.37625	.43887	.50148	.62663	.87665	1.00183	1.25102	1.87319	3.72702	4.98254	6.16972	7.37871
MEAS/DEGK	2.6578	2.2786	1.9941	1.5958	1.1407	.9985	.7994	.5338	.2683	.2019	.1621	.1355
MEAS/PSCHT	190.61039	154.85238	135.53386	108.48792	77.57820	67.91889	54.39581	36.36488	18.33326	13.82493	11.11967	9.31594

SURVIVABLE JUPITER PROBE TASK 3 DESCENT RUNS
JPL MONOGRAPH JUPITER COOL/DENSE ATMOSPHERE
BALLISTIC COEFFICIENT = 1.500, INITIAL TIME = 1794.91 SECONDS AT 71372.000 KM RADIUS

BAL. COEF. 0.65/0.09/1.50 SEP 10 BARS

RADIUS	71337.000 KM	ALTITUDE	-85.000 KM		PRESSURE	30.572251 BARS		TEMPERATURE	311.172 KELVIN			
			-278.871 KFT			30.172465 ATM			100.439 FAHRENHEIT			
TIME	2248.029 SEC	VELOCITY	63.226 METER/SEC		DYN P	.063787 BARS						
	37.46715 MIN		54.6088 MB/SEC		DOPPLER	4.584195E+02 CPS						
	.624452 HRS		207.435 FT/SEC		MACH NO	.052738						

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	751.34	644.29	564.01	451.61	373.15	283.00	226.80	151.87	76.93	58.20	46.96	39.47
KM/MEAS	.18948	.22102	.25255	.31558	.44151	.50441	.63022	.84350	1.87738	2.49478	3.10810	3.71743
MEAS/KM	5.2776	4.5244	3.9596	3.1687	2.2649	1.9825	1.5871	1.0599	.5327	.4008	.3217	.2690
BARS/MEAS	.16396	.19132	.21869	.27346	.38310	.43799	.54786	.82322	1.65498	2.21422	2.77724	3.34404
MEAS/BAR	6.0991	5.2269	4.5727	3.6569	2.6103	2.2832	1.8253	1.2147	.6042	.4516	.3601	.2990
DEGK/MEAS	.36820	.42949	.49076	.61324	.85794	.98016	1.22436	1.83338	3.64810	4.84780	6.03960	7.22364
MEAS/DEGK	2.7159	2.3284	2.0377	1.6307	1.1656	1.0202	.8168	.5454	.2741	.2063	.1656	.1384
MEAS/PSQFT	196.96182	160.29646	140.29744	112.29878	80.30026	70.30070	56.30127	37.63521	18.96849	14.30139	11.50088	9.63366

ADDITIONAL BIT RATES REQUIRED TO READ OUT ENTRY DATA
ONCE 3.028
TWICE 6.056

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P$INPT
 TITLE=50HSURVIVABLE SATURN  PROBE TASK 4 DESCENT RUNS          ,
 XNOTE=50H BAL. COEF.  0.65/0.70/1.50        SEP 30 BARS        ,
 BS=0.70,
 IATM=1,
$RSTART=59900.,      TSTART=0,
 RSTOP=59480.,     TSTOP=1.0E+08,
 DR=5.,
 STORD=7850.,
 FREQ=2.4E+09,     EZA=25.,
 XNAME=6H  TEMP,6H PRESS,6H  TEMP,5H PRESS,6H ACCEL,6H ACCEL,
      6H ACCEL,6H ACCEL,6HM SPEC,6HM SPEC,6HM SPEC,6HM SPEC,
 DTI(1,1)=3.,3.5,4.,5.,7.,8.,10.,15.,30.,40.,50.,60.,
 DTI(1,2)=3.,3.5,4.,5.,7.,8.,10.,15.,30.,40.,50.,60.,
 BPS(1,1)=10.,10.,10.,10.,30.,30.,30.,30.,400.,400.,400.,400.,
 BPS(1,2)=10.,10.,10.,10.,30.,30.,30.,30.,400.,400.,400.,400.,
 NSTAG=2,
 BCHG(2)=1.50,
 RCHG(2)=59484.0,
 $
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SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

SAMPLE INTERVALS (SECONDS)

TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
3.000	3.500	4.000	5.000	7.000	8.000	10.000	15.000	30.000	40.000	50.000	60.000

BITS PER SAMPLE

TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
10.000	10.000	10.000	10.000	30.000	30.000	30.000	30.000	400.000	400.000	400.000	400.000

NO OF PREVIOUS MEASUREMENTS

TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

REQUIRED BIT RATE = 61.7262 BITS/SECOND

ENTRY DATA IN STORAGE = 7850.0 BITS

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59900.000 KM		ALTITUDE	100.000 KM		PRESSURE	.048489 BARS		TEMPERATURE	77.000 KELVIN			
			328.084 KFT			.047855 ATM			-321.070 FAHRENHEIT			
TIME 0.	SEC	VELOCITY	365.969 METER/SEC		DYN P	.011521 BARS						
0.	MIN		.6592 MB/SEC		DOPPLER	2.653441E+03 CPS						
0.	HRS		1200.684 FT/SEC		MACH NO	.576276						
INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
KM/MEAS	1.08687	1.26590	1.44434	1.79945	2.50273	2.85036	3.54073	5.22747	9.99212	12.94934	15.75253	18.41690
MEAS/KM	.9201	.7900	.6924	.5557	.3996	.3508	.2824	.1913	.1001	.0772	.0635	.0543
BARS/MEAS	.00200	.00233	.00267	.00335	.00472	.00541	.00681	.01039	.02178	.02994	.03855	.04760
MEAS/BAR	500.8449	428.5737	374.3725	298.4959	211.7939	184.7037	146.7920	96.2769	45.9085	33.3998	25.9425	21.0077
DEGK/MEAS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MEAS/DEGK	R	R	R	R	R	R	R	R	R	R	R	R
MEAS/PSCHT	24.78203	21.27714	18.64843	14.95816	10.76190	9.44735	7.60682	5.15219	2.69520	2.07960	1.70945	1.46208

RADIUS 59895.000 KM		ALTITUDE	95.000 KM		PRESSURE	.058380 BARS		TEMPERATURE	77.000 KELVIN			
			311.680 KFT			.057617 ATM			-321.070 FAHRENHEIT			
TIME 14.317 SEC		VELOCITY	333.555 METER/SEC		DYN P	.011521 BARS						
.23861 MIN			.7234 MB/SEC		DOPPLER	2.418428E+03 CPS						
.003977 HRS			1094.341 FT/SEC		MACH NO	.525236						
INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	5.77	5.09	4.58	3.86	3.05	2.79	2.43	1.95	1.48	1.36	1.29	1.24
KM/MEAS	.99148	1.15497	1.31796	1.64247	2.28569	2.60444	3.23634	4.78438	9.17814	11.91995	14.52882	17.01705
MEAS/KM	1.0086	.8658	.7587	.6088	.4375	.3840	.3090	.2090	.1090	.0839	.0688	.0588
BARS/MEAS	.00219	.00256	.00293	.00367	.00517	.00593	.00746	.01135	.02371	.03251	.04176	.05146
MEAS/BAR	456.7412	390.8918	341.5063	272.3705	193.3689	169.6836	134.1364	88.0988	42.1739	30.7573	23.9449	19.4321
DEGK/MEAS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MEAS/DEGK	R	R	R	R	R	R	R	R	R	R	R	R
MEAS/PSCHT	27.16166	23.31684	20.43319	16.39601	11.78188	10.33997	8.32092	5.62844	2.33378	2.25885	1.85316	1.58213

RADIUS 59890.000 KM		ALTITUDE	90.000 KM		PRESSURE	.070292 BARS		TEMPERATURE	77.000 KELVIN			
			295.276 KFT			.069373 ATM			-321.070 FAHRENHEIT			
TIME 30.024 SEC		VELOCITY	304.008 METER/SEC		DYN P	.011521 BARS						
.50041 MIN			.7939 MB/SEC		DOPPLER	2.204196E+03 CPS						
.008340 HRS			997.401 FT/SEC		MACH NO	.478709						
INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	11.01	9.58	8.51	7.00	5.29	4.75	4.00	3.00	2.00	1.75	1.60	1.50
KM/MEAS	.90439	1.05365	1.20250	1.49898	2.08708	2.37874	2.95736	4.37728	8.42529	10.96416	13.38863	15.70855
MEAS/KM	1.1057	.9491	.8316	.6671	.4791	.4204	.3381	.2285	.1187	.0912	.0747	.0637
BARS/MEAS	.00240	.00281	.00321	.00402	.00567	.00649	.00816	.01241	.02583	.03534	.04529	.05570
MEAS/BAR	416.4823	356.4850	311.4883	248.4958	176.5125	154.0214	122.5394	80.5848	38.7168	28.2997	22.0787	17.9540
DEGK/MEAS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MEAS/DEGK	R	R	R	R	R	R	R	R	R	R	R	R
MEAS/PSCHT	29.77253	25.55475	22.39138	17.95260	12.90095	11.31910	9.10438	6.15092	3.19544	2.45540	2.01068	1.71367

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59885.000 KM ALTITUDE 85.000 KM PRESSURE .084636 BARS TEMPERATURE 77.000 KELVIN
278.871 KFT .083530 ATM -321.070 FAHRENHEIT
TIME 47.259 SEC VELOCITY 277.073 METER/SEC DYN P .011521 BARS
.78765 MIN .8712 MB/SEC DOPPLER 2.008911E+03 CPS
.013128 HRS 909.034 FT/SEC MACH NO .436296

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	16.75	14.50	12.81	10.45	7.75	6.91	5.73	4.15	2.88	2.18	1.95	1.79
KM/MEAS	.82487	.96113	1.09704	1.36784	1.90540	2.17218	2.70180	4.00349	7.72975	10.07790	12.32789	14.48746
MEAS/KM	1.2123	1.0404	.9115	.7311	.5248	.4604	.3701	.2498	.1294	.0992	.0811	.0690
BARS/MEAS	.00253	.00308	.00352	.00441	.00621	.00711	.00894	.01357	.02815	.03844	.04917	.06035
MEAS/BAR	379.7389	323.0747	284.0775	226.6837	161.0969	140.6038	111.9177	73.6859	35.5205	26.0177	20.3386	16.5705
DEGK/MEAS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MEAS/DEGK	R	R	R	R	R	R	R	R	R	R	R	R
MEAS/PSCHT	32.63717	28.01017	24.53990	19.68145	14.12877	12.39347	9.96395	6.72412	3.48243	2.67092	2.16337	1.85783

RADIUS 59880.000 KM ALTITUDE 80.000 KM PRESSURE .101911 BARS TEMPERATURE 77.000 KELVIN
262.467 KFT .100579 ATM -321.070 FAHRENHEIT
TIME 65.169 SEC VELOCITY 252.522 METER/SEC DYN P .011526 BARS
1.10282 MIN .9565 MB/SEC DOPPLER 1.830898E+03 CPS
.018380 HRS 828.483 FT/SEC MACH NO .397636

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	23.06	19.91	17.54	14.23	10.45	9.27	7.62	5.41	3.21	2.65	2.32	2.10
KM/MEAS	.75228	.87665	1.00073	1.24803	1.73925	1.98319	2.46778	3.66050	7.08782	9.25715	11.34240	13.43518
MEAS/KM	1.3293	1.1407	.9993	.8013	.5750	.5042	.4052	.2732	.1411	.1080	.0882	.0744
BARS/MEAS	.00289	.00337	.00386	.00484	.00680	.00779	.00979	.01485	.03070	.04184	.05342	.06597
MEAS/BAR	346.2091	293.4049	259.0524	206.7606	147.0034	128.3313	102.1936	67.3559	32.5690	23.9020	18.7195	15.1578
DEGK/MEAS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	.55684
MEAS/DEGK	R	R	R	R	R	R	R	R	R	R	R	1.7959
MEAS/PSCHT	35.78030	30.70430	26.89728	21.55739	15.47592	13.57227	10.90705	7.35300	3.79723	2.90728	2.37271	2.00333

RADIUS 59875.000 KM ALTITUDE 75.000 KM PRESSURE .122716 BARS TEMPERATURE 77.000 KELVIN
246.063 KFT .121111 ATM -321.070 FAHRENHEIT
TIME 85.918 SEC VELOCITY 230.142 METER/SEC DYN P .011526 BARS
1.44864 MIN 1.0497 MB/SEC DOPPLER 1.668634E+03 CPS
.024144 HRS 755.058 FT/SEC MACH NO .362395

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	29.97	25.83	22.73	18.38	13.42	11.86	9.69	6.79	3.90	3.17	2.74	2.45
KM/MEAS	.68603	.79953	.91278	1.13858	1.58735	1.81034	2.25357	3.34594	6.49596	8.53151	10.54232	12.51270
MEAS/KM	1.4577	1.2507	1.0956	.8783	.6300	.5524	.4437	.2989	.1539	.1172	.0949	.0799
BARS/MEAS	.00317	.00370	.00423	.00530	.00745	.00854	.01072	.01625	.03350	.04577	.05855	.07166
MEAS/BAR	315.6152	270.2407	236.2095	188.5672	134.1224	117.1100	93.2951	61.5514	29.8466	21.8507	17.0802	13.9556
DEGK/MEAS	0.	0.	0.	0.	0.	0.	0.	0.	0.	.65706	2.74923	4.79935
MEAS/DEGK	R	R	R	R	R	R	R	R	R	1.5219	.3637	.2084
MEAS/PSCHT	39.22904	33.66038	29.48386	23.63668	16.95405	14.86556	11.94182	8.04298	4.14255	3.15506	2.56359	2.17438

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59870.000 KM ALTITUDE 70.000 KM PRESSURE .147772 BARS TEMPERATURE 77.000 KELVIN
229.659 KFT .145840 ATM -321.070 FAHRENHEIT
TIME 103.685 SEC VELOCITY 209.742 METER/SEC DYN P .011526 BARS
1.92809 MIN 1.1520 MB/SEC DOPPLER 1.520727E+03 CPS
.030468 HRS 688.130 FT/SEC MACH NO .330272

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	37.56	32.34	28.42	22.94	16.67	14.71	11.97	8.31	4.66	3.74	3.19	2.83
KM/MEAS	.62558	.72914	.83250	1.03862	1.44852	1.65231	2.05758	3.06003	6.01630	7.93579	9.81799	11.66569
MEAS/KM	1.5985	1.3715	1.2012	.9628	.6904	.6052	.4860	.3268	.1662	.1260	.1019	.0857
BARS/MEAS	.00348	.00406	.00464	.00582	.00817	.00936	.01174	.01780	.03659	.04949	.06266	.07617
MEAS/BAR	287.7066	245.3665	215.3620	171.9565	122.3529	106.8530	85.1550	56.1877	27.3292	20.2058	15.9528	13.1283
DEGK/MEAS	0.	0.	0.	0.	0.	0.	0.	.16651	3.24239	5.23955	7.19791	9.12037
MEAS/DEGK	R	R	R	R	R	R	R	6.0057	.3084	.1909	.1389	.1096
MEAS/PSCHT	43.01317	36.30393	32.32199	25.90721	18.57591	16.28482	13.07720	8.79351	4.52008	3.46182	2.82798	2.40546

RADIUS 59865.000 KM ALTITUDE 65.000 KM PRESSURE .177757 BARS TEMPERATURE 79.185 KELVIN
213.255 KFT .175433 ATM -317.137 FAHRENHEIT
TIME 134.483 SEC VELOCITY 193.946 METER/SEC DYN P .011533 BARS
2.24139 MIN 1.2467 MB/SEC DOPPLER 1.406199E+03 CPS
.037356 HRS 636.306 FT/SEC MACH NO .301156

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	45.83	39.42	34.62	27.90	20.21	17.91	14.45	9.97	5.48	4.36	3.69	3.24
KM/MEAS	.57991	.67619	.77236	.95440	1.34722	1.53802	1.91841	2.86244	5.63844	7.44574	9.22120	10.96695
MEAS/KM	1.7244	1.4789	1.2947	1.0369	.7423	.6502	.5213	.3494	.1774	.1343	.1084	.0912
BARS/MEAS	.00375	.00438	.00501	.00627	.00879	.01006	.01260	.01900	.03862	.05204	.06573	.07968
MEAS/BAR	266.6141	228.3993	199.7385	159.6137	113.7579	99.4235	79.3680	52.6237	25.8915	19.2154	15.2140	12.5496
DEGK/MEAS	.60337	.70355	.80361	1.00342	1.40173	1.60025	1.99603	2.97826	5.86659	7.74702	9.59431	11.41070
MEAS/DEGK	1.6574	1.4214	1.2444	.9966	.7134	.6249	.5010	.3358	.1705	.1291	.1042	.0876
MEAS/PSCHT	47.89082	41.09760	35.00264	28.86959	20.71726	18.16934	14.60253	9.84579	5.08602	3.89431	3.17822	2.69999

RADIUS 59860.000 KM ALTITUDE 60.000 KM PRESSURE .211762 BARS TEMPERATURE 84.387 KELVIN
196.850 KFT .208993 ATM -307.773 FAHRENHEIT
TIME 160.995 SEC VELOCITY 183.453 METER/SEC DYN P .011533 BARS
2.68325 MIN 1.3182 MB/SEC DOPPLER 1.330116E+03 CPS
.044721 HRS 601.879 FT/SEC MACH NO .275942

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	54.67	47.00	41.25	33.20	24.00	21.12	17.10	11.73	6.37	5.02	4.22	3.68
KM/MEAS	.54873	.63988	.73093	.91278	1.27542	1.45622	1.81679	2.71236	5.35118	7.07311	8.76742	10.43527
MEAS/KM	1.8224	1.5628	1.3681	1.0956	.7841	.6867	.5504	.3687	.1869	.1414	.1141	.0958
BARS/MEAS	.00397	.00463	.00529	.00662	.00929	.01063	.01331	.02006	.04070	.05478	.06911	.08369
MEAS/BAR	252.1989	215.0637	188.9625	151.0211	107.6603	94.1104	75.1412	49.8511	24.5701	18.2552	14.4694	11.9488
DEGK/MEAS	.57034	.66577	.76051	.94971	1.32702	1.51514	1.89030	2.82210	5.56770	7.35930	9.12217	10.85140
MEAS/DEGK	1.7515	1.5020	1.3149	1.0530	.7535	.6600	.5290	.3543	.1796	.1359	.1096	.0922
MEAS/PSCHT	53.90462	46.25231	40.51304	32.47797	23.29479	20.42434	16.40697	11.04902	5.68837	4.34660	3.54057	3.00259

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59855.000 KM ALTITUDE 55.000 KM PRESSURE .249650 BARS TEMPERATURE 89.590 KELVIN
180.446 KFT .246386 ATM -298.409 FAHRENHEIT
TIME 188.977 SEC VELOCITY 174.104 METER/SEC DYN P .011533 BARS
3.14961 MIN 1.3893 MB/SEC DOPPLER 1.262334E+03 CPS
.052494 HRS 571.207 FT/SEC MACH NO .254163

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	63.99	54.99	48.24	38.80	28.00	24.52	19.90	13.60	7.30	5.72	4.78	4.15
KM/MEAS	.52093	.60749	.69397	.86671	1.21129	1.38313	1.72595	2.57797	5.09285	6.73640	8.39550	9.95152
MEAS/KM	1.9196	1.6461	1.4410	1.1538	.8255	.7230	.5794	.3879	.1964	.1484	.1197	.1005
BARS/MEAS	.00418	.00488	.00558	.00698	.00978	.01119	.01401	.02111	.04277	.05751	.07249	.08771
MEAS/BAR	239.3419	205.0596	179.3479	143.3518	102.2140	89.3588	71.3618	47.3676	23.3804	17.3890	13.7956	11.4016
DEGK/MEAS	.54201	.63207	.72205	.90178	1.26030	1.43910	1.79579	2.68228	5.29892	6.96907	8.61164	10.23078
MEAS/DEGK	1.8450	1.5821	1.3849	1.1089	.7935	.6949	.5569	.3728	.1887	.1435	.1161	.0977
MEAS/PSCHT	60.25040	51.69157	45.27242	36.28552	26.01455	22.80479	18.31095	12.31858	6.32376	4.82390	3.92286	3.32135

RADIUS 59850.000 KM ALTITUDE 50.000 KM PRESSURE .291602 BARS TEMPERATURE 94.792 KELVIN
164.042 KFT .287789 ATM -289.045 FAHRENHEIT
TIME 218.417 SEC VELOCITY 165.719 METER/SEC DYN P .011533 BARS
3.64029 MIN 1.4598 MB/SEC DOPPLER 1.201539E+03 CPS
.060671 HRS 543.697 FT/SEC MACH NO .235190

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	73.81	63.40	55.60	44.68	32.20	28.30	22.84	15.56	8.28	6.46	5.37	4.64
KM/MEAS	.49597	.57839	.66076	.82529	1.15357	1.31733	1.64408	2.45654	4.85776	6.43004	7.98087	9.51136
MEAS/KM	2.0163	1.7289	1.5134	1.2117	.8669	.7591	.6082	.4071	.2059	.1555	.1253	.1051
BARS/MEAS	.00439	.00512	.00586	.00733	.01028	.01175	.01472	.02216	.04485	.06026	.07591	.09178
MEAS/BAR	227.7984	195.1773	170.7115	136.4594	97.3145	85.0820	67.9567	45.1243	22.2974	16.5939	13.1736	10.8954
DEGK/MEAS	.50835	.59197	.67553	.84244	1.17543	1.34152	1.67310	2.49734	4.93336	6.52842	8.10173	9.65440
MEAS/DEGK	1.9672	1.6893	1.4803	1.1870	.8507	.7454	.5977	.4004	.2027	.1532	.1234	.1036
MEAS/PSCHT	66.92535	57.41274	50.27824	40.28983	28.87428	25.30682	20.31224	13.65225	6.99005	5.32318	4.32226	3.65434

RADIUS 59845.000 KM ALTITUDE 45.000 KM PRESSURE .337827 BARS TEMPERATURE 99.870 KELVIN
147.638 KFT .333409 ATM -279.905 FAHRENHEIT
TIME 249.316 SEC VELOCITY 158.048 METER/SEC DYN P .011546 BARS
4.15527 MIN 1.5327 MB/SEC DOPPLER 1.145918E+03 CPS
.069255 HRS 518.529 FT/SEC MACH NO .218526

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	84.11	72.23	63.33	50.86	36.62	32.16	25.93	17.62	9.31	7.23	5.99	5.16
KM/MEAS	.47311	.55176	.63035	.78737	1.10074	1.25708	1.56911	2.34537	4.64258	6.14905	7.63663	9.10620
MEAS/KM	2.1137	1.8124	1.5864	1.2700	.9085	.7955	.6373	.4264	.2154	.1626	.1309	.1098
BARS/MEAS	.00460	.00537	.00614	.00768	.01077	.01232	.01542	.02322	.04694	.06303	.07934	.09586
MEAS/BAR	217.2239	185.1238	162.7988	130.1440	92.8246	81.1624	64.8357	43.0678	21.3043	15.8660	12.6046	10.4316
DEGK/MEAS	.47996	.55975	.63949	.79876	1.11669	1.27530	1.59185	2.37936	4.70986	6.23816	7.74730	9.23817
MEAS/DEGK	2.0835	1.7865	1.5638	1.2519	.8955	.7841	.6282	.4203	.2123	.1603	.1291	.1082
MEAS/PSCHT	73.88296	63.37633	55.49634	44.45428	31.85603	27.91538	22.39953	15.04393	7.68632	5.84571	4.74061	4.00329

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59840.000 KM ALTITUDE 40.000 KM PRESSURE .388545 BARS TEMPERATURE 104.942 KELVIN
131.234 KFT .383464 ATM -270.774 FAHRENHEIT
TIME 281.678 SEC VELOCITY 151.081 METER/SEC DYN P .011546 BARS
4.69463 MIN 1.6036 MB/SEC DOPPLER 1.095405E+03 CPS
.078244 HRS 495.671 FT/SEC MACH NO .203782

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	94.89	81.48	71.42	57.34	41.24	36.21	29.17	19.78	10.39	8.04	6.63	5.69
KM/MEAS	.45234	.52755	.60272	.75291	1.05269	1.20229	1.50091	2.24411	4.44605	5.89198	7.32119	8.73439
MEAS/KM	2.2107	1.8953	1.6591	1.3282	.9499	.8317	.6663	.4456	.2249	.1697	.1366	.1145
BARS/MEAS	.00482	.00562	.00643	.00804	.01127	.01289	.01613	.02427	.04903	.06579	.08276	.09994
MEAS/BAR	207.6200	177.9008	155.6114	124.4064	88.7438	77.5934	61.9974	41.1956	20.3973	15.1939	12.0826	10.0055
DEGK/MEAS	.45890	.53520	.61146	.75382	1.06795	1.21971	1.52266	2.27663	4.51048	5.97737	7.42729	8.86098
MEAS/DEGK	2.1791	1.8685	1.6354	1.3092	.9364	.8199	.6567	.4392	.2217	.1673	.1346	.1129
MEAS/PSCHT	81.16852	69.62120	60.96061	48.83572	34.97854	30.64810	24.58537	16.50129	8.41538	6.39279	5.17856	4.36853

RADIUS 59835.000 KM ALTITUDE 35.000 KM PRESSURE .443945 BARS TEMPERATURE 110.014 KELVIN
114.829 KFT .438140 ATM -261.644 FAHRENHEIT
TIME 315.495 SEC VELOCITY 144.728 METER/SEC DYN P .011546 BARS
5.25826 MIN 1.6743 MB/SEC DOPPLER 1.049342E+03 CPS
.087638 HRS 474.828 FT/SEC MACH NO .190659

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	106.17	91.14	79.87	64.10	46.07	40.44	32.55	22.03	11.52	8.89	7.31	6.26
KM/MEAS	.43339	.50547	.57751	.72145	1.00882	1.15225	1.43860	2.15152	4.26590	5.65598	7.03120	8.39214
MEAS/KM	2.3074	1.9783	1.7316	1.3861	.9913	.8679	.6951	.4648	.2344	.1768	.1422	.1192
BARS/MEAS	.00503	.00587	.00671	.00839	.01175	.01345	.01683	.02533	.05111	.06855	.08619	.10403
MEAS/BAR	198.8570	173.3970	149.0520	119.1691	85.0175	74.3452	59.4042	39.4835	19.5657	14.5879	11.6023	9.6127
DEGK/MEAS	.43967	.51280	.58588	.73191	1.02344	1.16835	1.45944	2.18271	4.32773	5.73796	7.13310	8.51377
MEAS/DEGK	2.2744	1.9501	1.7068	1.3663	.9771	.8555	.6852	.4581	.2311	.1743	.1402	.1175
MEAS/PSCHT	88.78064	76.14580	65.66964	53.40297	38.24091	33.50270	26.86910	18.02390	9.17701	6.96427	5.63599	4.74997

RADIUS 59830.000 KM ALTITUDE 30.000 KM PRESSURE .504216 BARS TEMPERATURE 115.087 KELVIN
98.425 KFT .497623 ATM -252.513 FAHRENHEIT
TIME 350.763 SEC VELOCITY 138.909 METER/SEC DYN P .011546 BARS
5.84605 MIN 1.7447 MB/SEC DOPPLER 1.007158E+03 CPS
.097434 HRS 455.740 FT/SEC MACH NO .178917

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	117.92	101.22	88.69	71.15	51.11	44.85	36.08	24.38	12.69	9.77	8.02	6.85
KM/MEAS	.41603	.48524	.55440	.69262	.96860	1.10636	1.38144	2.06653	4.10017	5.43859	6.76373	8.07609
MEAS/KM	2.4037	2.0608	1.8037	1.4438	1.0324	.9039	.7239	.4839	.2439	.1839	.1478	.1238
BARS/MEAS	.00524	.00612	.00699	.00874	.01225	.01401	.01754	.02638	.05319	.07131	.08962	.10811
MEAS/BAR	190.8277	163.5209	143.0408	114.3688	81.6009	71.3611	57.0254	37.9117	18.8003	14.0239	11.1588	9.2495
DEGK/MEAS	.42206	.49227	.56244	.70266	.98264	1.122+0	1.40146	2.09648	4.15960	5.51741	6.86175	8.19313
MEAS/DEGK	2.3693	2.0314	1.7780	1.4232	1.0177	.8909	.7135	.4770	.2404	.1812	.1457	.1221
MEAS/PSCHT	96.71758	82.94889	72.62236	58.15516	41.64251	36.47912	29.25028	19.61145	9.97107	7.56004	6.11283	5.14756

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.060 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59825.000 KM ALTITUDE 25.000 KM PRESSURE .569545 BARS TEMPERATURE 120.159 KELVIN
82.021 KFT .562098 ATM -243.383 FAHRENHEIT
TIME 387.475 SEC VELOCITY 133.561 METER/SEC DYN P .011546 BARS
6.45792 MIN 1.8149 MB/SEC DOPPLER 9.683758E+02 CPS
.107632 HRS 438.191 FT/SEC MACH NO .158357

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	130.16	111.71	97.87	78.50	56.35	49.43	39.75	26.83	13.92	10.69	8.75	7.46
KM/MEAS	.40007	.46662	.53315	.66610	.93159	1.06413	1.32882	1.98823	3.94720	5.23768	6.51626	7.78336
MEAS/KM	2.4996	2.1431	1.8757	1.5013	1.0734	.9397	.7525	.5030	.2533	.1909	.1535	.1285
BARS/MEAS	.00545	.00636	.00727	.00909	.01275	.01457	.01824	.02742	.05527	.07406	.09304	.11220
MEAS/BAR	183.4425	157.1960	137.5111	109.9522	78.4566	68.6143	54.8352	36.4635	18.0937	13.5023	10.7482	8.9127
DEGK/MEAS	.40586	.47339	.54088	.67575	.94509	1.07955	1.34808	2.01705	4.00440	5.31359	6.61070	7.89616
MEAS/DEGK	2.4639	2.1124	1.8489	1.4798	1.0581	.9263	.7418	.4958	.2497	.1882	.1513	.1266
MEAS/PSCHT	104.97805	90.02930	78.81772	63.12147	45.18275	39.57686	31.72851	21.26370	10.79745	8.18001	6.60901	5.56123

RADIUS 59820.000 KM ALTITUDE 20.000 KM PRESSURE .640118 BARS TEMPERATURE 125.232 KELVIN
65.617 KFT .631747 ATM -234.253 FAHRENHEIT
TIME 425.627 SEC VELOCITY 128.626 METER/SEC DYN P .011546 BARS
7.09378 MIN 1.8848 MB/SEC DOPPLER 9.325945E+02 CPS
.118230 HRS 422.000 FT/SEC MACH NO .158819

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	142.88	122.61	107.41	85.13	61.80	54.20	43.56	29.38	15.19	11.64	9.51	8.09
KM/MEAS	.38533	.44944	.51353	.64161	.89741	1.02513	1.28021	1.91585	3.80555	5.05136	6.28622	7.51060
MEAS/KM	2.5952	2.2250	1.9473	1.5586	1.1143	.9755	.7811	.5220	.2628	.1980	.1591	.1331
BARS/MEAS	.00566	.00661	.00755	.00945	.01324	.01513	.01894	.02847	.05734	.07681	.09646	.11628
MEAS/BAR	176.6260	151.3575	132.4064	105.8747	75.5529	66.0774	52.8118	35.1247	17.4392	13.0190	10.3674	8.6000
DEGK/MEAS	.39091	.45596	.52097	.65091	.91041	1.03938	1.29876	1.94362	3.86070	5.11718	6.34397	7.56034
MEAS/DEGK	2.5581	2.1932	1.9195	1.5363	1.0984	.9616	.7700	.5145	.2590	.1954	.1576	.1323
MEAS/PSCHT	113.56075	97.38590	85.25475	68.27110	48.86110	42.79542	34.30339	22.98036	11.65600	8.82423	7.12470	5.99114

RADIUS 59815.000 KM ALTITUDE 15.000 KM PRESSURE .716120 BARS TEMPERATURE 130.298 KELVIN
49.213 KFT .706755 ATM -225.134 FAHRENHEIT
TIME 465.213 SEC VELOCITY 124.054 METER/SEC DYN P .011552 BARS
7.75355 MIN 1.9556 MB/SEC DOPPLER 8.994518E+02 CPS
.129226 HRS 407.003 FT/SEC MACH NO .150167

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	156.07	133.92	117.30	94.04	67.45	59.15	47.52	32.01	16.51	12.63	10.30	8.75
KM/MEAS	.37157	.43352	.49534	.61890	.86569	.98832	1.23507	1.84857	3.67338	4.87727	6.07138	7.25601
MEAS/KM	2.6906	2.3067	2.0188	1.6158	1.1551	1.0112	.8097	.5410	.2722	.2050	.1647	.1378
BARS/MEAS	.00587	.00685	.00783	.00979	.01373	.01559	.01963	.02952	.05942	.07958	.09990	.12040
MEAS/BAR	170.3072	145.9450	127.6733	102.0931	72.8586	63.7229	50.9330	33.8800	16.8284	12.5663	10.0095	8.3054
DEGK/MEAS	.36924	.43068	.49210	.61485	.86003	.98246	1.22700	1.83648	3.64937	4.84539	6.03170	7.20858
MEAS/DEGK	2.7083	2.3219	2.0321	1.6264	1.1627	1.0179	.8150	.5445	.2740	.2064	.1656	.1387
MEAS/PSCHT	122.45964	105.01327	91.92847	73.60972	52.67390	46.13141	36.97184	24.75680	12.54453	9.49021	7.65715	6.43473

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59810.000 KM ALTITUDE 10.000 KM PRESSURE .797771 BARS TEMPERATURE 135.265 KELVIN
32.808 KFT .787339 ATM -216.192 FAHRENHEIT
TIME 505.237 SEC VELOCITY 119.764 METER/SEC DYN P .011552 BARS
8.43729 MIN 2.0260 MB/SEC DOPPLER 8.683448E+02 CPS
.140621 HRS 392.927 FT/SEC MACH NO .142287

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	169.75	145.64	127.56	102.25	73.32	64.28	51.62	34.75	17.87	13.66	11.12	9.44
KM/MEAS	.35885	.41857	.47826	.59758	.83593	.95496	1.19272	1.78545	3.54950	4.71410	5.86984	7.01698
MEAS/KM	2.7867	2.3891	2.0909	1.5734	1.1963	1.0472	.8384	.5601	.2817	.2121	.1704	.1425
BARS/MEAS	.00608	.00710	.00811	.01015	.01422	.01626	.02034	.03057	.06152	.08236	.10336	.12453
MEAS/BAR	164.3776	140.8658	123.2319	98.5446	70.3306	61.5138	49.1703	32.7125	16.2559	12.1424	9.6747	8.0299
DEGK/MEAS	.35650	.41583	.47514	.59368	.83047	.94872	1.18493	1.77378	3.52630	4.68329	5.83148	6.97112
MEAS/DEGK	2.8050	2.4048	2.1046	1.5844	1.2041	1.0541	.8439	.5638	.2836	.2135	.1715	.1434
MEAS/PSCHT	131.63506	112.87792	98.81004	79.11499	56.60625	49.57223	39.72452	26.59398	13.46228	10.17866	8.20805	6.89395

RADIUS 59805.000 KM ALTITUDE 5.000 KM PRESSURE .885294 BARS TEMPERATURE 140.233 KELVIN
16.404 KFT .873717 ATM -207.251 FAHRENHEIT
TIME 549.704 SEC VELOCITY 115.768 METER/SEC DYN P .011552 BARS
9.14507 MIN 2.0953 MB/SEC DOPPLER 8.393737E+02 CPS
.152418 HRS 379.817 FT/SEC MACH NO .135082

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	183.90	157.77	138.18	110.74	79.39	69.59	55.87	37.58	19.29	14.72	11.97	10.15
KM/MEAS	.34690	.40464	.46236	.57773	.80820	.92330	1.15325	1.72659	3.43383	4.56162	5.68129	6.79306
MEAS/KM	2.8827	2.4713	2.1628	1.7309	1.2373	1.0831	.8671	.5792	.2912	.2192	.1760	.1472
BARS/MEAS	.00630	.00735	.00840	.01050	.01471	.01682	.02104	.03162	.06361	.08513	.10682	.12867
MEAS/BAR	158.8535	135.1338	119.0940	95.2382	67.9745	59.4548	47.5271	31.6237	15.7212	11.7462	9.3616	7.7721
DEGK/MEAS	.34464	.40200	.45934	.57395	.80292	.91727	1.14571	1.71530	3.41138	4.53181	5.63707	6.72999
MEAS/DEGK	2.9016	2.4875	2.1770	1.7423	1.2455	1.0902	.8728	.5830	.2931	.2207	.1774	.1486
MEAS/PSCHT	141.13143	121.01766	105.93232	84.81282	60.67614	53.13339	42.57347	28.49333	14.41211	10.89115	8.77826	7.36929

RADIUS 59800.000 KM ALTITUDE 0. KM PRESSURE .978881 BARS TEMPERATURE 145.200 KELVIN
0. KFT .966080 ATM -198.310 FAHRENHEIT
TIME 592.611 SEC VELOCITY 112.038 METER/SEC DYN P .011554 BARS
9.87685 MIN 2.1669 MB/SEC DOPPLER 8.123237E+02 CPS
.164614 HRS 367.577 FT/SEC MACH NO .128473

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	198.34	170.32	149.15	119.52	85.65	75.08	60.26	40.51	20.75	15.82	12.85	10.88
KM/MEAS	.33575	.39163	.44750	.55917	.78228	.89371	1.11634	1.67151	3.32538	4.41847	5.50420	6.58252
MEAS/KM	2.9784	2.5534	2.2346	1.7884	1.2783	1.1189	.8958	.5983	.3007	.2263	.1817	.1519
BARS/MEAS	.00651	.00759	.00868	.01085	.01520	.01738	.02174	.03267	.06570	.08792	.11029	.13281
MEAS/BAR	153.6936	131.7133	115.2261	92.1489	65.7727	57.5302	45.9907	30.6049	15.2199	11.3741	9.0670	7.5293
DEGK/MEAS	.33006	.38500	.43992	.54970	.76902	.87856	1.09741	1.64318	3.26901	4.34358	5.41091	6.45372
MEAS/DEGK	3.0298	2.5974	2.2732	1.8192	1.3004	1.1382	.9112	.6086	.3059	.2302	.1848	.1549
MEAS/PSCHT	150.94709	129.43096	113.29384	90.70186	64.88236	56.81372	45.51758	30.45581	15.39304	11.62674	9.36658	7.85970

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59795.000 KM ALTITUDE -5.000 KM PRESSURE 1.078744 BARS TEMPERATURE 150.115 KELVIN
-16.404 KFT 1.064637 ATM -189.463 FAHRENHEIT
TIME 637.959 SEC VELOCITY 108.526 METER/SEC DYN P .011554 BARS
10.63265 MIN 2.2374 MB/SEC DOPPLER 7.868650E+02 CPS
.177211 HRS 356.057 FT/SEC MACH NO .122392

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	213.65	183.27	160.49	128.59	92.14	80.74	64.80	43.53	22.27	16.95	13.76	11.63
KM/MEAS	.32525	.37939	.43351	.54171	.75788	.86536	1.08158	1.61962	3.22297	4.28310	5.33642	6.38306
MEAS/KM	3.0746	2.6358	2.3067	1.8460	1.3195	1.1549	.9246	.6174	.3103	.2335	.1874	.1567
BARS/MEAS	.00672	.00784	.00896	.01121	.01570	.01735	.02245	.03373	.06781	.09072	.11378	.13700
MEAS/BAR	148.8371	127.5529	111.5897	89.2412	63.7002	55.7187	44.5448	29.6460	14.7473	11.0229	8.7886	7.2992
DEGK/MEAS	.31973	.37296	.42617	.53253	.74504	.85118	1.05867	1.57399	3.10967	4.12506	5.13391	6.13638
MEAS/DEGK	3.1276	2.6813	2.3465	1.8778	1.3422	1.1748	.9446	.6353	.3216	.2424	.1948	.1630
MEAS/PSCHT	161.05663	138.09628	120.87600	96.75759	69.21503	60.60432	48.55072	32.47789	16.40347	12.38419	9.97225	8.36398

RADIUS 59790.000 KM ALTITUDE -10.000 KM PRESSURE 1.185129 BARS TEMPERATURE 154.927 KELVIN
-32.808 KFT 1.169631 ATM -180.801 FAHRENHEIT
TIME 684.758 SEC VELOCITY 105.196 METER/SEC DYN P .011578 BARS
11.41263 MIN 2.3133 MB/SEC DOPPLER 7.627180E+02 CPS
.190211 HRS 345.130 FT/SEC MACH NO .116780

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	229.25	196.65	172.19	137.95	98.82	86.59	69.48	46.65	23.83	18.12	14.70	12.41
KM/MEAS	.31528	.36777	.42024	.52513	.73471	.83939	1.04857	1.57034	3.12583	4.15482	5.17755	6.19417
MEAS/KM	3.1718	2.7191	2.3796	1.9043	1.3611	1.1913	.9537	.6368	.3199	.2407	.1931	.1614
BARS/MEAS	.00693	.00809	.00925	.01156	.01620	.01852	.02316	.03480	.06994	.09356	.11732	.14123
MEAS/BAR	144.2285	123.6043	108.1362	86.4808	61.7318	53.9978	43.1702	28.7335	14.2975	10.6888	8.5238	7.0807
DEGK/MEAS	.30197	.35225	.40250	.50296	.70370	.80337	1.00431	1.50406	2.99390	3.97945	4.95902	5.93273
MEAS/DEGK	3.3115	2.8389	2.4845	1.9882	1.4211	1.2436	.9957	.6649	.3340	.2513	.2017	.1686
MEAS/PSCHT	171.42890	146.98648	128.65466	102.99007	73.65905	64.49307	51.66064	34.55054	17.43956	13.16128	10.59397	8.88216

RADIUS 59785.000 KM ALTITUDE -15.000 KM PRESSURE 1.296301 BARS TEMPERATURE 159.716 KELVIN
-49.213 KFT 1.281323 ATM -172.181 FAHRENHEIT
TIME 733.018 SEC VELOCITY 102.056 METER/SEC DYN P .011578 BARS
12.21696 MIN 2.3849 MB/SEC DOPPLER 7.399562E+02 CPS
.203616 HRS 334.831 FT/SEC MACH NO .111583

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	245.34	210.43	184.25	147.60	105.72	92.53	74.30	49.87	25.43	19.33	15.66	13.22
KM/MEAS	.30589	.35682	.40773	.50951	.71288	.81447	1.01747	1.52391	3.03422	4.03376	5.02756	6.01574
MEAS/KM	3.2692	2.8025	2.4526	1.9627	1.4028	1.2278	.9828	.6562	.3296	.2479	.1989	.1662
BARS/MEAS	.00715	.00834	.00953	.01192	.01670	.01909	.02388	.03587	.07208	.09639	.12085	.14546
MEAS/BAR	139.8855	119.8835	104.8820	83.8799	59.8775	52.3758	41.8758	27.8746	13.8740	10.3741	8.2744	6.8747
DEGK/MEAS	.29298	.34176	.39052	.48800	.68279	.78009	.97452	1.45959	2.90616	3.86350	4.81536	5.76183
MEAS/DEGK	3.4132	2.9261	2.5607	2.0492	1.4645	1.2819	1.0261	.6851	.3441	.2588	.2077	.1736
MEAS/PSCHT	182.11303	156.14431	135.66775	109.40055	78.23797	68.49953	54.86590	36.68740	18.50809	13.96275	11.23523	9.41663

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59780.000 KM ALTITUDE -20.000 KM PRESSURE 1.416474 BARS TEMPERATURE 164.505 KELVIN
-65.617 KFT 1.399925 ATM -163.561 FAHRENHEIT
TIME 782.740 SEC VELOCITY 99.099 METER/SEC DYN P .011578 BARS
13.04567 MIN 2.4565 MB/SEC DOPPLER 7.185131E+02 CPS
.217428 HRS 325.128 FT/SEC MACH NO .106761

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	261.91	224.64	196.68	157.55	112.82	98.94	79.27	53.18	27.09	20.57	16.65	14.05
KM/MEAS	.29704	.34650	.39594	.49478	.69230	.79037	.98815	1.48013	2.94779	3.91948	4.88590	5.84714
MEAS/KM	3.3665	2.8860	2.5256	2.0211	1.4445	1.2643	1.0120	.6756	.3392	.2551	.2047	.1710
BARS/MEAS	.00736	.00859	.00982	.01228	.01720	.01957	.02460	.03695	.07421	.09924	.12440	.14970
MEAS/BAR	135.7935	116.3776	101.8156	81.4290	58.1300	50.8430	40.6558	27.0649	13.4744	10.0770	8.0388	6.6801
DEGK/MEAS	.28450	.33187	.37923	.47390	.66308	.75759	.94645	1.41765	2.82337	3.75405	4.67968	5.60035
MEAS/DEGK	3.5149	3.0132	2.6369	2.1102	1.5081	1.3200	1.0566	.7054	.3542	.2664	.2137	.1786
MEAS/PSCHT	193.11899	165.57799	144.92222	116.00413	82.95481	72.62687	58.16770	38.88853	19.60878	14.78834	11.89578	9.96716

RADIUS 59775.000 KM ALTITUDE -25.000 KM PRESSURE 1.545860 BARS TEMPERATURE 169.294 KELVIN
-82.021 KFT 1.525645 ATM -154.941 FAHRENHEIT
TIME 833.924 SEC VELOCITY 96.308 METER/SEC DYN P .011578 BARS
13.89874 MIN 2.5281 MB/SEC DOPPLER 6.982771E+02 CPS
.231646 HRS 315.971 FT/SEC MACH NO .102276

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	278.97	239.26	209.48	167.78	120.13	105.24	84.39	56.59	28.80	21.85	17.68	14.90
KM/MEAS	.28869	.33676	.38481	.49089	.67288	.76830	.96048	1.43878	2.86610	3.81143	4.75190	5.68759
MEAS/KM	3.4639	2.9695	2.5987	2.0795	1.4862	1.3017	1.0412	.6950	.3489	.2624	.2104	.1758
BARS/MEAS	.00758	.00884	.01011	.01264	.01771	.02024	.02531	.03802	.07636	.10208	.12794	.15394
MEAS/BAR	131.9312	113.0684	98.9214	79.1155	56.4802	49.4057	39.5038	26.3001	13.0967	9.7961	7.8159	6.4958
DEGK/MEAS	.27650	.32254	.36857	.45059	.64448	.73635	.91994	1.37805	2.74512	3.65056	4.55133	5.44753
MEAS/DEGK	3.6165	3.1004	2.7132	2.1711	1.5515	1.3581	1.0870	.7257	.3643	.2739	.2197	.1836
MEAS/PSCHT	204.44659	175.28744	153.41799	122.80074	87.80954	76.87476	61.56602	41.13420	20.74164	15.63805	12.57561	10.53375

RADIUS 59770.000 KM ALTITUDE -30.000 KM PRESSURE 1.680672 BARS TEMPERATURE 174.083 KELVIN
-98.425 KFT 1.658695 ATM -146.321 FAHRENHEIT
TIME 885.571 SEC VELOCITY 93.670 METER/SEC DYN P .011578 BARS
14.77618 MIN 2.5997 MB/SEC DOPPLER 6.791483E+02 CPS
.246270 HRS 307.315 FT/SEC MACH NO .098096

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	296.52	254.31	222.64	178.31	127.65	111.82	89.66	60.10	30.55	23.16	18.73	15.78
KM/MEAS	.28079	.32755	.37429	.46775	.65451	.74792	.93430	1.39967	2.78878	3.70911	4.62496	5.53639
MEAS/KM	3.5613	3.0530	2.6717	2.1379	1.5279	1.3372	1.0703	.7145	.3586	.2696	.2162	.1806
BARS/MEAS	.00780	.00910	.01040	.01300	.01821	.02081	.02603	.03910	.07850	.10493	.13150	.15820
MEAS/BAR	128.2799	109.9400	96.1850	76.9281	54.9203	48.0429	38.4145	25.5767	12.7392	9.5301	7.6047	6.3212
DEGK/MEAS	.26894	.31372	.35850	.44801	.62689	.71626	.89487	1.34059	2.67107	3.55256	4.42975	5.30271
MEAS/DEGK	3.7183	3.1875	2.7894	2.2321	1.5952	1.3951	1.1175	.7459	.3744	.2815	.2257	.1886
MEAS/PSCHT	216.09602	185.27258	162.15499	129.79034	92.80211	81.24326	65.06083	43.48409	21.90666	16.51187	13.27473	11.11641

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59765.000 KM ALTITUDE -35.000 KM PRESSURE 1.823125 BARS TEMPERATURE 178.872 KELVIN
-114.829 KFT 1.799284 ATM -137.701 FAHRENHEIT
TIME 940.680 SEC VELOCITY 91.172 METER/SEC DYN P .011578 BARS
15.57800 MIN 2.6714 MB/SEC DOPPLER 6.610398E+02 CPS
.261300 HRS 299.121 FT/SEC MACH NO .094194

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	314.56	269.77	236.17	189.14	135.38	118.59	95.07	63.71	32.36	24.52	19.81	16.68
KM/MEAS	.27332	.31883	.36433	.45531	.63712	.72796	.90951	1.36262	2.71549	3.61210	4.50455	5.39291
MEAS/KM	3.6588	3.1365	2.7447	2.1963	1.5696	1.3737	1.0995	.7339	.3683	.2768	.2220	.1854
BARS/MEAS	.00801	.00935	.01068	.01336	.01871	.02139	.02675	.04017	.08064	.10778	.13506	.16246
MEAS/BAR	124.8227	106.9777	93.5941	74.8569	53.4430	46.7512	37.3827	24.8914	12.4004	9.2778	7.4044	6.1555
DEGK/MEAS	.26178	.30537	.34896	.43609	.61023	.69723	.87112	1.30511	2.60087	3.45964	4.31442	5.16528
MEAS/DEGK	3.8200	3.2747	2.8657	2.2931	1.6387	1.4342	1.1479	.7662	.3845	.2890	.2318	.1936
MEAS/PSCHT	228.06691	195.53333	171.13315	136.97286	97.93248	85.73234	68.65210	45.87829	23.10382	17.40979	13.96312	11.71513

RADIUS 59760.000 KM ALTITUDE -40.000 KM PRESSURE 1.973431 BARS TEMPERATURE 183.661 KELVIN
-131.234 KFT 1.947625 ATM -129.081 FAHRENHEIT
TIME 996.252 SEC VELOCITY 88.804 METER/SEC DYN P .011578 BARS
16.60420 MIN 2.7431 MB/SEC DOPPLER 6.438704E+02 CPS
.276737 HRS 291.352 FT/SEC MACH NO .090543

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	333.08	285.64	250.06	200.25	143.32	125.53	100.63	67.42	34.21	25.91	20.93	17.60
KM/MEAS	.26623	.31056	.35489	.44351	.62063	.70912	.88600	1.32747	2.64592	3.51997	4.39017	5.25057
MEAS/KM	3.7562	3.2200	2.8178	2.2548	1.6113	1.4102	1.1287	.7533	.3779	.2841	.2278	.1902
BARS/MEAS	.00823	.00960	.01097	.01372	.01922	.02197	.02747	.04125	.08279	.11064	.13862	.16672
MEAS/BAR	121.5445	104.1689	91.1371	72.8928	52.0421	45.5252	36.4041	24.2413	12.0767	9.0382	7.2141	5.9980
DEGK/MEAS	.25499	.29745	.33991	.42479	.59443	.67919	.84860	1.27144	2.53424	3.37140	4.20487	5.03470
MEAS/DEGK	3.9217	3.3619	2.9420	2.3541	1.6823	1.4723	1.1784	.7865	.3946	.2966	.2378	.1986
MEAS/PSCHT	240.35924	206.06962	180.35240	144.34826	103.20062	90.34136	72.33980	48.33677	24.33311	18.33131	14.73079	12.32990

RADIUS 59755.000 KM ALTITUDE -45.000 KM PRESSURE 2.131804 BARS TEMPERATURE 188.450 KELVIN
-147.638 KFT 2.103927 ATM -120.461 FAHRENHEIT
TIME 1053.286 SEC VELOCITY 86.556 METER/SEC DYN P .011578 BARS
17.55477 MIN 2.8148 MB/SEC DOPPLER 6.275692E+02 CPS
.292579 HRS 283.976 FT/SEC MACH NO .087122

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	352.10	301.94	264.32	211.66	151.47	132.56	106.33	71.22	36.11	27.33	22.07	18.55
KM/MEAS	.25950	.30271	.34592	.43230	.60495	.69123	.86366	1.29409	2.57980	3.43239	4.28139	5.12687
MEAS/KM	3.8536	3.3035	2.8908	2.3132	1.6530	1.4467	1.1579	.7727	.3876	.2913	.2336	.1951
BARS/MEAS	.00844	.00985	.01126	.01408	.01972	.02254	.02819	.04233	.08494	.11350	.14219	.17099
MEAS/BAR	118.4317	101.5017	88.8042	71.0276	50.7115	44.3629	35.4746	23.6237	11.7730	8.8105	7.0331	5.8482
DEGK/MEAS	.24854	.28994	.33132	.41406	.57943	.66210	.82721	1.23947	2.47092	3.28752	4.10066	4.91047
MEAS/DEGK	4.0234	3.4490	3.0182	2.4151	1.7258	1.5104	1.2089	.8066	.4047	.3042	.2439	.2036
MEAS/PSCHT	252.97295	216.88137	189.81267	151.91648	108.60643	95.07210	76.12391	50.85952	25.59454	19.27793	15.46772	12.96073

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59750.000 KM ALTITUDE -50.000 KM PRESSURE 2.298460 BARS TEMPERATURE 193.239 KELVIN
-164.042 KFT 2.268403 ATM -111.840 FAHRENHEIT
TIME 1111.783 SEC VELOCITY 84.418 METER/SEC DYN P .011578 BARS
18.52972 MIN 2.8866 MB/SEC DOPPLER 6.120719E+02 CPS
.308829 HRS 276.963 FT/SEC MACH NO .083912

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	371.59	318.65	278.95	223.36	159.83	139.97	112.18	75.12	38.06	28.79	23.24	19.53
KM/MEAS	.25310	.29525	.33739	.42165	.59007	.67422	.84243	1.26233	2.51689	3.34902	4.17782	5.00333
MEAS/KM	3.9511	3.3870	2.9639	2.3716	1.6947	1.4832	1.1870	.7922	.3973	.2986	.2394	.1999
BARS/MEAS	.00866	.01010	.01155	.01444	.02022	.02312	.02891	.04341	.08709	.11636	.14576	.17527
MEAS/BAR	115.4722	98.9658	86.5859	69.2542	49.4465	43.2556	34.5908	23.0363	11.4821	8.5937	6.8607	5.7054
DEGK/MEAS	.24241	.28279	.32315	.40385	.56515	.64576	.80687	1.20905	2.41065	3.20766	4.00148	4.79215
MEAS/DEGK	4.1252	3.5362	3.0945	2.4761	1.7694	1.5486	1.2394	.8271	.4148	.3118	.2499	.2087
MEAS/PSCHT	265.90794	227.96850	193.51391	159.67746	114.15005	99.92272	80.00441	53.44653	26.88809	20.24813	16.26393	13.60761

RADIUS 59745.000 KM ALTITUDE -55.000 KM PRESSURE 2.473612 BARS TEMPERATURE 198.028 KELVIN
-180.446 KFT 2.441265 ATM -103.220 FAHRENHEIT
TIME 1171.743 SEC VELOCITY 82.384 METER/SEC DYN P .011578 BARS
19.52905 MIN 2.9583 MB/SEC DOPPLER 5.973205E+02 CPS
.325484 HRS 270.288 FT/SEC MACH NO .080893

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	391.58	335.78	293.94	235.35	168.39	147.47	118.17	79.12	40.06	30.29	24.43	20.53
KM/MEAS	.24700	.28814	.32927	.41151	.57588	.65802	.82220	1.23209	2.45694	3.26956	4.07908	4.88553
MEAS/KM	4.0485	3.4705	3.0370	2.4301	1.7365	1.5197	1.2162	.8116	.4070	.3059	.2452	.2047
BARS/MEAS	.00888	.01036	.01184	.01480	.02073	.02359	.02963	.04449	.08925	.11923	.14933	.17955
MEAS/BAR	112.6549	96.5517	84.4742	67.5658	48.2420	42.2033	33.7491	22.4770	11.2050	8.3871	6.6964	5.5693
DEGK/MEAS	.23658	.27598	.31538	.39414	.55158	.63025	.78750	1.18008	2.35324	3.13156	3.90691	4.67932
MEAS/DEGK	4.2269	3.6234	3.1708	2.5372	1.8130	1.5867	1.2698	.8474	.4249	.3193	.2560	.2137
MEAS/PSCHT	279.16413	239.33094	203.45604	167.63117	119.83127	104.89378	83.98126	56.09778	28.21375	21.24241	17.05939	14.27054

RADIUS 59740.000 KM ALTITUDE -60.000 KM PRESSURE 2.657475 BARS TEMPERATURE 202.817 KELVIN
-196.850 KFT 2.622724 ATM -94.600 FAHRENHEIT
TIME 1233.166 SEC VELOCITY 80.445 METER/SEC DYN P .011578 BARS
20.55276 MIN 3.0302 MB/SEC DOPPLER 5.832621E+02 CPS
.342546 HRS 263.927 FT/SEC MACH NO .078051

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	412.06	353.33	309.29	247.63	177.17	155.15	124.32	83.21	42.11	31.83	25.66	21.55
KM/MEAS	.24120	.28137	.32154	.40184	.56237	.64238	.80293	1.20326	2.39977	3.19376	3.98485	4.77308
MEAS/KM	4.1460	3.5540	3.1101	2.4885	1.7782	1.5562	1.2454	.8311	.4167	.3131	.2510	.2095
BARS/MEAS	.00909	.01061	.01213	.01516	.02123	.02427	.03035	.04557	.09140	.12210	.15291	.18384
MEAS/BAR	109.9697	94.2507	82.4615	65.9566	47.0939	41.1933	32.9468	21.9436	10.9406	8.1899	6.5396	5.4394
DEGK/MEAS	.23102	.26949	.30796	.38488	.53863	.61546	.76904	1.15247	2.29848	3.05696	3.81666	4.57182
MEAS/DEGK	4.3287	3.7107	3.2471	2.5982	1.8565	1.6248	1.3003	.8677	.4351	.3269	.2620	.2187
MEAS/PSCHT	292.74143	250.96863	213.63902	175.77755	125.65011	109.98526	88.05445	58.81324	29.57152	22.26077	17.87412	14.94951

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59735.000 KM ALTITUDE -65.000 KM PRESSURE 2.850264 BARS TEMPERATURE 207.606 KELVIN
-213.255 KFT 2.812992 ATM -85.980 FAHRENHEIT
TIME 1295.051 SEC VELOCITY 78.595 METER/SEC DYN P .011578 BARS
21.50085 MIN 3.1020 MB/SEC DOPPLER 5.698491E+02 CPS
.358014 HRS 257.857 FT/SEC MACH NO .075371

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	433.02	371.30	325.01	260.21	186.15	163.01	130.61	87.40	44.20	33.40	26.92	22.60
KM/MEAS	.23566	.27431	.31415	.39262	.54947	.62735	.78453	1.17574	2.34517	3.12136	3.89483	4.66562
MEAS/KM	4.2435	3.6376	3.1832	2.5470	1.8199	1.5927	1.2747	.8505	.4264	.3204	.2568	.2143
BARS/MEAS	.00931	.01085	.01242	.01552	.02174	.02435	.03107	.04665	.09356	.12497	.15650	.18814
MEAS/BAR	107.4076	92.0553	80.5410	64.4210	45.9982	40.2411	32.1812	21.4346	10.6882	8.0016	6.3898	5.3152
DEGK/MEAS	.22571	.26330	.30089	.37605	.52628	.60135	.75142	1.12611	2.24619	2.98908	3.72924	4.46684
MEAS/DEGK	4.4305	3.7979	3.3235	2.6592	1.9001	1.6629	1.3308	.8880	.4452	.3346	.2682	.2239
MEAS/PSCHT	306.63978	262.88149	230.06277	184.11654	131.60653	115.19713	92.22394	61.59291	30.96138	23.30321	18.70810	15.64453

RADIUS 59730.000 KM ALTITUDE -70.000 KM PRESSURE 3.052197 BARS TEMPERATURE 212.392 KELVIN
-229.659 KFT 3.012284 ATM -77.364 FAHRENHEIT
TIME 1360.400 SEC VELOCITY 76.828 METER/SEC DYN P .011586 BARS
22.67334 MIN 3.1761 MB/SEC DOPPLER 5.570350E+02 CPS
.377889 HRS 252.059 FT/SEC MACH NO .072842

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	454.47	389.69	341.10	273.08	195.34	171.05	137.04	91.69	46.35	35.01	28.21	23.67
KM/MEAS	.23035	.26873	.30710	.38381	.53714	.61377	.76695	1.14943	2.29298	3.05212	3.80872	4.56281
MEAS/KM	4.3410	3.7212	3.2563	2.6055	1.8617	1.6293	1.3039	.8700	.4361	.3276	.2626	.2192
BARS/MEAS	.00953	.01112	.01271	.01588	.02225	.02543	.03180	.04774	.09572	.12785	.16009	.19244
MEAS/BAR	104.9597	89.9576	78.7060	62.9538	44.9513	39.3256	31.4495	20.9481	10.4468	7.8216	6.2465	5.1964
DEGK/MEAS	.22044	.25716	.29387	.35728	.51401	.58734	.73392	1.09994	2.19423	2.92069	3.64471	4.36632
MEAS/DEGK	4.5363	3.8886	3.4028	2.7227	1.9455	1.7026	1.3625	.9091	.4557	.3424	.2744	.2290
MEAS/PSCHT	320.85743	275.06804	240.72598	192.64710	137.69975	120.52859	96.48918	64.43638	32.38311	24.36950	19.56115	16.35543

RADIUS 59725.000 KM ALTITUDE -75.000 KM PRESSURE 3.263491 BARS TEMPERATURE 217.177 KELVIN
-246.063 KFT 3.220815 ATM -68.751 FAHRENHEIT
TIME 1425.213 SEC VELOCITY 75.137 METER/SEC DYN P .011586 BARS
23.77022 MIN 3.2481 MB/SEC DOPPLER 5.447804E+02 CPS
.396170 HRS 246.514 FT/SEC MACH NO .070450

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	476.40	408.49	357.55	285.24	204.74	179.28	143.62	96.06	48.54	36.06	29.52	24.77
KM/MEAS	.22930	.26283	.30035	.37538	.52535	.60030	.75013	1.12427	2.24303	2.98585	3.72628	4.46436
MEAS/KM	4.4385	3.8048	3.3294	2.6640	1.9035	1.6658	1.3331	.8895	.4458	.3349	.2684	.2240
BARS/MEAS	.00974	.01137	.01300	.01625	.02275	.02601	.03252	.04882	.09789	.13073	.16369	.19675
MEAS/BAR	102.6185	87.9514	76.9511	61.5506	43.9500	38.4439	30.7496	20.4827	10.2158	7.6492	6.1093	5.0827
DEGK/MEAS	.21550	.25151	.28742	.35921	.50273	.57445	.71783	1.07586	2.14644	2.85727	3.56582	4.27212
MEAS/DEGK	4.6383	3.9760	3.4793	2.7839	1.9891	1.7418	1.3931	.9295	.4659	.3500	.2804	.2341
MEAS/PSCHT	335.39452	287.52839	251.62879	201.36934	143.92992	125.98009	100.85029	67.34379	33.83684	25.45983	20.43344	17.08237

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59720.000 KM ALTITUDE -80.000 KM PRESSURE 3.484364 BARS TEMPERATURE 221.962 KELVIN
-262.467 KFT 3.438800 ATM -60.139 FAHRENHEIT
TIME 1493.490 SEC VELOCITY 73.520 METER/SEC DYN P .011586 BARS
24.89150 MIN 3.3201 MB/SEC DOPPLER 5.330517E+02 CPS
.414858 HRS 241.206 FT/SEC MACH NO .068186

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	498.83	427.71	374.37	299.70	214.35	187.59	150.35	100.57	50.78	38.34	30.87	25.89
KM/MEAS	.22045	.25718	.29389	.35731	.51407	.58741	.73403	1.10018	2.19519	2.92237	3.64730	4.37003
MEAS/KM	4.5361	3.8884	3.4026	2.7226	1.9453	1.7024	1.3623	.9089	.4555	.3422	.2742	.2288
BARS/MEAS	.00996	.01162	.01329	.01661	.02325	.02659	.03325	.04991	.10005	.13362	.16729	.20106
MEAS/BAR	100.3778	85.0312	75.2713	60.2074	42.9915	37.6116	30.0797	20.0371	9.9947	7.4841	5.9778	4.9737
DEGK/MEAS	.21096	.24610	.28124	.35149	.49193	.56212	.70242	1.05280	2.10066	2.79652	3.49024	4.18185
MEAS/DEGK	4.7402	4.0634	3.5557	2.8450	2.0328	1.7790	1.4236	.9498	.4760	.3576	.2865	.2391
MEAS/PSCHT	350.25250	300.26380	262.77227	210.28412	150.29762	131.55182	105.30768	70.31938	35.32266	26.57421	21.32497	17.82534

RADIUS 59715.000 KM ALTITUDE -85.000 KM PRESSURE 3.715033 BARS TEMPERATURE 226.746 KELVIN
-278.871 KFT 3.666453 ATM -51.526 FAHRENHEIT
TIME 1562.232 SEC VELOCITY 71.970 METER/SEC DYN P .011586 BARS
26.03719 MIN 3.3922 MB/SEC DOPPLER 5.218159E+02 CPS
.433953 HRS 236.122 FT/SEC MACH NO .066041

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	521.74	447.35	391.56	313.45	224.18	196.28	157.22	105.15	53.07	40.06	32.24	27.04
KM/MEAS	.21581	.25175	.28770	.35958	.50325	.57536	.71861	1.07710	2.14934	2.86151	3.57155	4.27944
MEAS/KM	4.6337	3.9720	3.4758	2.7810	1.9871	1.7389	1.3916	.9284	.4653	.3495	.2800	.2337
BARS/MEAS	.01018	.01188	.01358	.01697	.02377	.02717	.03397	.05039	.10222	.13650	.17089	.20537
MEAS/BAR	98.2310	84.1915	73.6620	58.9205	42.0732	36.8034	29.4377	19.6101	9.7826	7.3258	5.8516	4.8692
DEGK/MEAS	.20652	.24092	.27532	.34409	.48158	.55030	.68766	1.03071	2.05678	2.73828	3.41317	4.07167
MEAS/DEGK	4.8422	4.1508	3.6322	2.9062	2.0765	1.8172	1.4542	.9702	.4862	.3652	.2930	.2456
MEAS/PSCHT	365.43133	313.27422	274.15639	219.39140	156.80282	137.24337	109.86131	73.35114	36.84056	27.71266	22.23587	18.58464

RADIUS 59710.000 KM ALTITUDE -90.000 KM PRESSURE 3.955723 BARS TEMPERATURE 231.488 KELVIN
-295.276 KFT 3.903995 ATM -42.991 FAHRENHEIT
TIME 1632.441 SEC VELOCITY 70.478 METER/SEC DYN P .011595 BARS
27.20735 MIN 3.4671 MB/SEC DOPPLER 5.109947E+02 CPS
.453456 HRS 231.226 FT/SEC MACH NO .064006

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	545.15	467.41	409.11	327.49	234.21	205.06	164.24	109.83	55.41	41.81	33.65	28.21
KM/MEAS	.21134	.24654	.28174	.35213	.49283	.56315	.70373	1.05463	2.10502	2.80262	3.49820	4.19180
MEAS/KM	4.7317	4.0561	3.5493	2.8399	2.0291	1.7757	1.4210	.9480	.4751	.3568	.2859	.2386
BARS/MEAS	.01040	.01213	.01387	.01734	.02428	.02775	.03470	.05209	.10441	.13942	.17453	.20975
MEAS/BAR	96.1630	82.4192	72.1115	57.6806	41.1861	36.0342	28.8188	19.1982	9.5777	7.1727	5.7297	4.7677
DEGK/MEAS	.19659	.22934	.26209	.32756	.45845	.52396	.65464	.98123	1.95816	2.60708	3.25414	3.89935
MEAS/DEGK	5.0865	4.3603	3.8155	3.0529	2.1813	1.9089	1.5276	1.0191	.5107	.3836	.3073	.2565
MEAS/PSCHT	380.89384	326.52747	285.75258	228.55797	163.42827	143.04035	114.49843	76.44179	38.38475	28.87025	23.16139	19.35536

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59705.000 KM ALTITUDE -95.000 KM PRESSURE +.206758 BARS TEMPERATURE 236.140 KELVIN
-311.680 KFT 4.151748 ATM -34.619 FAHRENHEIT

TIME 1704.129 SEC VELOCITY 69.031 METER/SEC DYN P .011595 BARS
28.4021 MIN 3.5403 MB/SEC DOPPLER 5.005088E+02 CPS
.473369 HRS 226.481 FT/SEC MACH NO .052072

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	569.04	487.89	427.03	341.83	244.45	214.32	171.41	114.61	57.80	43.60	35.08	29.46
KM/MEAS	.20701	.24149	.27597	.34491	.48274	.55162	.68933	1.03327	2.06218	2.74573	3.42740	4.10719
MEAS/KM	4.8308	4.1410	3.6236	2.8993	2.0715	1.8128	1.4507	.9678	.4849	.3642	.2918	.2435
BARS/MEAS	.01052	.01239	.01416	.01771	.02479	.02834	.03544	.05319	.10661	.14235	.17819	.21414
MEAS/BAR	94.1398	80.7026	70.6097	56.4797	40.3311	35.2846	28.2196	18.7996	9.3797	7.0248	5.6118	4.6699
DEGK/MEAS	.19256	.22464	.25671	.32085	.44906	.51314	.64124	.96118	1.91831	2.55417	3.18328	3.82064
MEAS/DEGK	5.1931	4.4519	3.8954	3.1167	2.2269	1.9488	1.5595	1.0404	.5213	.3915	.3136	.2617
MEAS/PSCHT	396.60712339.99599297.53764238.09593170.16252148.93331119.21240								79.58443	39.35609	30.04877	24.10423	20.14108

RADIUS 59700.000 KM ALTITUDE -100.000 KM PRESSURE 4.466404 BARS TEMPERATURE 240.791 KELVIN
-328.084 KFT 4.409971 ATM -26.247 FAHRENHEIT

TIME 1777.305 SEC VELOCITY 67.642 METER/SEC DYN P .011595 BARS
29.62174 MIN 3.6137 MB/SEC DOPPLER 4.904347E+02 CPS
.493696 HRS 221.922 FT/SEC MACH NO .050232

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	593.43	508.30	445.33	355.46	254.90	223.16	178.73	119.49	60.24	45.43	36.55	30.62
KM/MEAS	.20284	.23663	.27042	.33798	.47304	.54034	.67550	1.01256	2.02101	2.69105	3.35932	4.02581
MEAS/KM	4.9293	4.2259	3.6980	2.9588	2.1140	1.8500	1.4804	.9876	.4948	.3716	.2977	.2484
BARS/MEAS	.01084	.01265	.01446	.01807	.02531	.02893	.03617	.05430	.10882	.14529	.18187	.21854
MEAS/BAR	92.2352	79.0533	69.1668	55.3258	39.5075	34.5844	27.6439	18.4166	9.1894	6.8826	5.4986	4.5759
DEGK/MEAS	.18869	.22012	.25155	.31440	.44004	.50233	.62837	.94191	1.88001	2.50330	3.12495	3.74494
MEAS/DEGK	5.2997	4.5429	3.9753	3.1807	2.2725	1.9897	1.5914	1.0617	.5319	.3995	.3200	.2670
MEAS/PSCHT	+12.64372353.74164309.56508247.71768177.03531549.47021249.02337								82.79174	41.55976	31.25153	25.06646	20.94296

RADIUS 59695.000 KM ALTITUDE -105.000 KM PRESSURE 4.740893 BARS TEMPERATURE 245.442 KELVIN
-344.488 KFT 4.678898 ATM -17.875 FAHRENHEIT

TIME 1851.969 SEC VELOCITY 66.306 METER/SEC DYN P .011595 BARS
30.86614 MIN 3.6871 MB/SEC DOPPLER 4.807487E+02 CPS
.514435 HRS 217.539 FT/SEC MACH NO .056480

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	618.32	530.13	463.99	371.39	265.57	232.30	186.20	124.46	62.73	47.30	38.04	31.87
KM/MEAS	.19884	.23196	.26508	.33131	.46372	.52939	.66219	.99264	1.98140	2.63844	3.29381	3.94750
MEAS/KM	5.0292	4.3110	3.7724	3.0183	2.1565	1.8892	1.5101	1.0074	.5047	.3790	.3036	.2533
BARS/MEAS	.01106	.01291	.01475	.01844	.02583	.02952	.03691	.05541	.11103	.14824	.18554	.22295
MEAS/BAR	90.3847	77.4674	67.7795	54.2164	38.7156	33.8718	27.0903	18.0482	9.0063	6.7458	5.3896	4.4854
DEGK/MEAS	.18437	.21576	.24659	.30820	.43135	.49232	.61593	.92338	1.84316	2.45437	3.06401	3.67210
MEAS/DEGK	5.4254	4.6343	4.0553	3.2447	2.3182	2.0287	1.6234	1.0830	.5425	.4074	.3264	.2723
MEAS/PSCHT	+29.00385367.76461321.83517257.53395184.04680161.08215128.95139								86.06376	43.19577	32.47856	26.04816	21.76101

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59690.000 KM ALTITUDE -110.000 KM PRESSURE 5.024461 BARS TEMPERATURE 250.092 KELVIN
-360.892 KFT 4.958758 ATM -9.505 FAHRENHEIT
TIME 1923.123 SEC VELOCITY 65.020 METER/SEC DYN P .011606 BARS
32.13538 MIN 3.7642 MB/SEC DOPPLER 4.714279E+02 CPS
.535590 HRS 213.322 FT/SEC MACH NO .056811

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	643.71	551.89	483.03	385.62	270.45	242.02	193.81	129.54	65.27	49.20	39.56	33.14
KM/MEAS	.19499	.22747	.25995	.32490	.45474	.51963	.64938	.97345	1.34322	2.58771	3.23060	3.87190
MEAS/KM	5.1286	4.3962	3.8469	3.0779	2.1991	1.924+	1.5399	1.0273	.5146	.3864	.3095	.2583
BARS/MEAS	.01129	.01317	.01505	.01882	.02635	.03012	.03765	.05652	.11325	.15120	.18924	.22737
MEAS/BAR	88.6037	75.9412	66.4442	53.1486	37.9535	33.2051	26.5572	17.6935	8.8298	6.6139	5.2844	4.3981
DEGK/MEAS	.17908	.20692	.23875	.29840	.41765	.47725	.59641	.89405	1.78473	2.37666	2.96711	3.55611
MEAS/DEGK	5.5840	4.7865	4.1865	3.3512	2.3944	2.0953	1.6767	1.1185	.5603	.4208	.3370	.2812
MEAS/PSCHT	+45.68557	382.06316	334.34627	257.54262	191.19555	167.33708	133.93521	89.39929	44.86304	33.72877	27.04808	22.59418

RADIUS 59685.000 KM ALTITUDE -115.000 KM PRESSURE 5.319381 BARS TEMPERATURE 254.684 KELVIN
-377.297 KFT 5.249821 ATM -1.239 FAHRENHEIT
TIME 2003.773 SEC VELOCITY 63.775 METER/SEC DYN P .011606 BARS
33.42955 MIN 3.8383 MB/SEC DOPPLER 4.623991E+02 CPS
.557159 HRS 209.236 FT/SEC MACH NO .055218

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	669.59	574.08	502.44	402.15	287.54	251.72	201.58	134.72	67.86	51.14	41.12	34.43
KM/MEAS	.19125	.22312	.25498	.31868	.44604	.50970	.63697	.95487	1.30627	2.53862	3.16945	3.79878
MEAS/KM	5.2285	4.4820	3.9219	3.1379	2.2419	1.9619	1.5699	1.0473	.5246	.3939	.3155	.2632
BARS/MEAS	.01151	.01343	.01535	.01919	.02687	.03071	.03840	.05764	.11549	.15417	.19295	.23183
MEAS/BAR	86.8789	74.4630	65.1511	52.1144	37.2154	32.5534	26.0411	17.3500	8.6590	6.4863	5.1826	4.3136
DEGK/MEAS	.17566	.20492	.23418	.29269	.40965	.46813	.58502	.87639	1.75079	2.33157	2.91095	3.48895
MEAS/DEGK	5.6929	4.8800	4.2702	3.4166	2.4410	2.1362	1.7093	1.1403	.5712	.4289	.3435	.2866
MEAS/PSCHT	+62.64158	396.59679	347.06319	277.71615	198.46236	173.69533	139.02196	92.79046	46.35863	35.00048	28.06546	23.44201

RADIUS 59680.000 KM ALTITUDE -120.000 KM PRESSURE 5.625927 BARS TEMPERATURE 259.276 KELVIN
-393.701 KFT 5.552358 ATM 7.027 FAHRENHEIT
TIME 2084.927 SEC VELOCITY 62.575 METER/SEC DYN P .011606 BARS
34.74878 MIN 3.9126 MB/SEC DOPPLER 4.536985E+02 CPS
.579146 HRS 205.299 FT/SEC MACH NO .053697

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	695.98	596.69	522.23	417.99	298.85	261.62	209.49	140.00	70.50	53.12	42.70	35.75
KM/MEAS	.18756	.21892	.25018	.31269	.43765	.50013	.62501	.93697	1.87064	2.49128	3.11049	3.72827
MEAS/KM	5.3288	4.5678	3.9971	3.1980	2.2849	1.9995	1.6000	1.0673	.5346	.4014	.3215	.2682
BARS/MEAS	.01173	.01369	.01565	.01956	.02739	.03131	.03915	.05876	.11773	.15715	.19667	.23629
MEAS/BAR	85.2157	73.0385	63.9049	51.1178	36.5040	31.9372	25.5437	17.0190	8.4943	6.3632	5.0845	4.2321
DEGK/MEAS	.17235	.20107	.22978	.28719	.40197	.45934	.57404	.86035	1.71807	2.28809	2.85679	3.42419
MEAS/DEGK	5.8020	4.9735	4.3520	3.4820	2.4879	2.1770	1.7420	1.1621	.5820	.4370	.3500	.2920
MEAS/PSCHT	+79.92278	411.40924	360.02408	288.08486	205.86857	180.17597	144.20630	96.24666	48.28675	36.29658	29.10235	24.30610

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59675.000 KM ALTITUDE -125.000 KM PRESSURE 5.944343 BARS TEMPERATURE 263.068 KELVIN
-410.105 KFT 5.866610 ATM 19.293 FAHRENHEIT
TIME 2165.584 SEC VELOCITY 61.418 METER/SEC DYN P .011605 BARS
36.09307 MIN 3.9870 MB/SEC DOPPLER 4.453068E+02 CPS
.601551 HRS 201.503 FT/SEC MACH NO .052244

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	722.86	619.74	542.40	434.12	310.37	271.70	217.56	145.37	73.19	55.14	44.31	37.09
KM/MEAS	.18419	.21488	.24556	.30691	.42958	.49093	.61348	.91976	1.83628	2.44562	3.05359	3.66022
MEAS/KM	5.4292	4.6538	4.0723	3.2582	2.3278	2.0371	1.6300	1.0873	.5446	.4089	.3275	.2732
BARS/MEAS	.01196	.01395	.01595	.01994	.02792	.03191	.03990	.05988	.11997	.16014	.20041	.24076
MEAS/BAR	83.6139	71.6649	62.7032	50.1568	35.8180	31.3372	25.0640	16.6997	8.3339	6.2445	4.9899	4.1535
DEGK/MEAS	.16917	.19735	.22553	.28188	.39455	.45086	.56344	.84469	1.68851	2.24615	2.80454	3.36169
MEAS/DEGK	5.9113	5.0671	4.4340	3.5476	2.5345	2.2180	1.7748	1.1839	.5929	.4452	.3566	.2975
MEAS/PSCHT	+97.52958	+26.50078	373.22918	298.04892	213.41432	186.77850	149.48833	99.70803	50.04743	37.61709	30.15878	25.18646

RADIUS 59570.000 KM ALTITUDE -130.000 KM PRESSURE 6.274874 BARS TEMPERATURE 268.461 KELVIN
-426.509 KFT 6.192819 ATM 23.559 FAHRENHEIT
TIME 2247.749 SEC VELOCITY 60.301 METER/SEC DYN P .011606 BARS
37.46248 MIN 4.0615 MB/SEC DOPPLER 4.372136E+02 CPS
.624375 HRS 197.839 FT/SEC MACH NO .050853

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	750.25	643.21	562.94	450.55	322.11	281.37	225.77	150.85	75.92	57.19	45.95	38.46
KM/MEAS	.18084	.21097	.24110	.30134	.42179	.48139	.60235	.90303	1.80311	2.40153	2.99867	3.59452
MEAS/KM	5.5296	4.7399	4.1477	3.3185	2.3709	2.0747	1.6602	1.1074	.5546	.4164	.3335	.2782
BARS/MEAS	.01219	.01422	.01625	.02031	.02844	.03251	.04065	.06101	.12222	.16314	.20414	.24524
MEAS/BAR	82.0674	70.3396	61.5437	49.2295	35.1561	30.7582	24.6011	16.3916	8.1822	6.1299	4.8985	4.0776
DEGK/MEAS	.16609	.19377	.22144	.27676	.38738	.44238	.55322	.82938	1.65605	2.20566	2.75409	3.30135
MEAS/DEGK	6.0207	5.1608	4.5160	3.6132	2.5814	2.2598	1.8076	1.2057	.6038	.4534	.3631	.3029
MEAS/PSCHT	515.46229	+41.87167	386.67870	309.40854	221.09976	193.50325	154.86812	103.35455	51.84070	38.96205	31.23475	25.08312

RADIUS 59465.000 KM ALTITUDE -135.000 KM PRESSURE 6.617767 BARS TEMPERATURE 273.053 KELVIN
-442.913 KFT 6.531228 ATM 31.825 FAHRENHEIT
TIME 2331.421 SEC VELOCITY 59.224 METER/SEC DYN P .011605 BARS
38.85702 MIN 4.1361 MB/SEC DOPPLER 4.293978E+02 CPS
.647617 HRS 194.303 FT/SEC MACH NO .049523

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	778.14	667.12	583.86	467.28	334.05	292.43	234.14	156.43	78.71	59.29	47.63	39.86
KM/MEAS	.17751	.20721	.23679	.29596	.41425	.47339	.59161	.88694	1.77107	2.35895	2.94260	3.53103
MEAS/KM	5.6302	4.8261	4.2231	3.3768	2.4140	2.1124	1.6903	1.1275	.5646	.4239	.3398	.2832
BARS/MEAS	.01241	.01448	.01655	.02069	.02897	.03311	.04140	.06213	.12447	.16614	.20789	.24973
MEAS/BAR	80.5742	69.0599	60.4242	48.3342	34.5170	30.1931	24.1541	16.0941	8.0342	6.0192	4.8102	4.0043
DEGK/MEAS	.16313	.19031	.21748	.27182	.38047	.43478	.54335	.81460	1.62662	2.10655	2.70936	3.23901
MEAS/DEGK	6.1302	5.2547	4.5981	3.6789	2.6283	2.3000	1.8404	1.2276	.6148	.4616	.3696	.3087
MEAS/PSCHT	533.72123	457.52219	400.37290	320.35389	228.92500	200.35033	160.34579	107.00632	53.66658	40.33148	32.33030	26.99617

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59660.000 KM ALTITUDE -140.000 KM PRESSURE 6.973271 BARS TEMPERATURE 277.627 KELVIN
-459.318 KFT 6.882084 ATM 40.059 FAHRENHEIT
TIME 2415.605 SEC VELOCITY 58.180 METER/SEC DYN P .011620 BARS
40.27676 MIN 4.2162 MB/SEC DOPPLER 4.218338E+02 CPS
.671279 HRS 190.880 FT/SEC MACH NO .048248

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	806.54	591.46	605.15	484.32	346.23	303.08	242.66	162.11	81.55	61.42	49.33	41.28
KM/MEAS	.17449	.20356	.23262	.29075	.40697	.46506	.58120	.87136	1.74003	2.31768	2.89415	3.46947
MEAS/KM	5.7311	4.9126	4.2988	3.4394	2.4572	2.1503	1.7206	1.1476	.5747	.4315	.3455	.2882
BARS/MEAS	.01254	.01474	.01685	.02107	.02950	.03372	.04216	.06327	.12673	.16915	.21106	.25425
MEAS/BAR	79.1291	67.8214	59.3406	47.4676	33.8983	29.6579	23.7214	15.8060	7.8907	5.9119	4.7246	3.9331
DEGK/MEAS	.15862	.18505	.21148	.25432	.36997	.42278	.52837	.79214	1.58185	2.10698	2.63105	3.15406
MEAS/DEGK	6.3042	5.4039	4.7286	3.7833	2.7029	2.3653	1.8926	1.2624	.6322	.4746	.3801	.3171
MEAS/PSCHT	552.28841473	439.43679414	329.07331	250.86236	188.88207	147.31250165	105.91535110	70.71909	55.52257	41.72327	33.44358	27.92371

RADIUS 59655.000 KM ALTITUDE -145.000 KM PRESSURE 7.341683 BARS TEMPERATURE 282.173 KELVIN
-475.722 KFT 7.245678 ATM 48.241 FAHRENHEIT
TIME 2503.307 SEC VELOCITY 57.169 METER/SEC DYN P .011620 BARS
41.72178 MIN 4.2915 MB/SEC DOPPLER 4.145002E+02 CPS
.695363 HRS 187.562 FT/SEC MACH NO .047026

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	835.44	716.23	626.83	501.66	358.62	313.31	251.33	167.89	84.44	63.38	51.07	42.72
KM/MEAS	.17145	.20002	.22858	.28570	.39990	.45699	.57112	.85625	1.70996	2.27769	2.84431	3.40983
MEAS/KM	5.8324	4.9995	4.3748	3.5002	2.5005	2.1883	1.7510	1.1679	.5848	.4390	.3516	.2933
BARS/MEAS	.01287	.01501	.01716	.02145	.03003	.03432	.04291	.06440	.12900	.17218	.21544	.25876
MEAS/BAR	77.7281	65.6208	58.2902	46.6275	33.2985	29.1334	23.3020	15.5268	7.7517	5.8080	4.6417	3.8642
DEGK/MEAS	.15587	.18184	.20780	.25973	.36355	.41544	.51920	.77841	1.55451	2.07063	2.58674	3.09985
MEAS/DEGK	6.4157	5.4994	4.8122	3.8502	2.7507	2.4071	1.9260	1.2847	.6433	.4829	.3867	.3226
MEAS/PSCHT	571.15526489	489.60839428	408.44821342	342.82397244	264.96766214	214.38756171	157.57539114	104.49249	87.40925	63.13628	54.57560	28.86706

RADIUS 59650.000 KM ALTITUDE -150.000 KM PRESSURE 7.723268 BARS TEMPERATURE 286.718 KELVIN
-492.126 KFT 7.622273 ATM 56.423 FAHRENHEIT
TIME 2591.530 SEC VELOCITY 56.190 METER/SEC DYN P .011620 BARS
43.19217 MIN 4.3670 MB/SEC DOPPLER 4.074070E+02 CPS
.719869 HRS 184.352 FT/SEC MACH NO .045853

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	864.84	741.44	648.88	519.31	371.22	324.94	250.15	173.77	87.38	65.79	52.83	44.19
KM/MEAS	.16852	.19660	.22468	.28082	.39307	.44918	.56136	.84164	1.68086	2.23900	2.79609	3.35212
MEAS/KM	5.9339	5.0865	4.4509	3.5610	2.5441	2.2263	1.7814	1.1882	.5949	.4466	.3576	.2983
BARS/MEAS	.01309	.01528	.01746	.02183	.03055	.03493	.04368	.06554	.13128	.17521	.21923	.26333
MEAS/BAR	76.3732	65.4595	57.2743	45.8149	32.7185	28.6250	22.8963	15.2566	7.6173	5.7074	4.5615	3.7976
DEGK/MEAS	.15320	.17873	.20425	.25529	.35733	.40834	.51033	.76513	1.52805	2.03546	2.54190	3.04738
MEAS/DEGK	6.5273	5.5951	4.8960	3.9171	2.7985	2.4489	1.9595	1.3070	.6544	.4913	.3934	.3282
MEAS/PSCHT	590.35017506	506.06115442	428.44438354	354.08925353	274.19403221	224.58352177	173.33384118	118.33141	89.32872	64.67730	55.72730	29.62682

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59643.000 KM ALTITUDE -157.000 KM PRESSURE 8.118280 BARS TEMPERATURE 291.204 KELVIN
-508.930 KFT 8.012120 ATM 64.605 FAHRENHEIT
TIME 2681.277 SEC VELOCITY 55.244 METER/SEC DYN P .011620 BARS
44.68795 MIN 4.4426 MB/SEC DOPPLER 4.005428E+02 CPS
.744799 HRS 181.246 FT/SEC MACH NO .044727

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	894.75	767.08	671.32	537.26	384.04	336.16	269.13	179.75	90.38	68.03	54.03	45.69
KM/MEAS	.16958	.19329	.22089	.27609	.38645	.44152	.55192	.82756	1.65269	2.20155	2.74939	3.29624
MEAS/KM	6.0356	5.1736	4.5271	3.6220	2.5875	2.2644	1.8119	1.2085	.6051	.4542	.3637	.3034
BARS/MEAS	.01332	.01554	.01776	.02221	.03110	.03554	.04444	.06659	.13356	.17825	.22302	.26788
MEAS/BAR	75.0619	64.3357	56.2911	45.0206	32.1572	28.1349	22.5037	14.9954	7.4871	5.6100	4.4838	3.7330
DEGK/MEAS	.15062	.17572	.20061	.25099	.35132	.40147	.50175	.75227	1.50244	2.00140	2.49945	2.99658
MEAS/DEGK	6.6391	5.6909	4.9838	3.9842	2.8464	2.4908	1.9930	1.3293	.6656	.4996	.4001	.3337
MEAS/PSCHT	509.873+6522.79E39457.48684366.05485261.56113226.90584183.19081122.23605 61.28104 46.04214 36.89870 30.80300											

RADIUS 59640.000 KM ALTITUDE -160.000 KM PRESSURE 8.526977 BARS TEMPERATURE 295.609 KELVIN
-524.934 KFT 8.415472 ATM 72.786 FAHRENHEIT
TIME 2772.550 SEC VELOCITY 54.327 METER/SEC DYN P .011620 BARS
46.20917 MIN 4.5183 MB/SEC DOPPLER 3.936988E+02 CPS
.770153 HRS 178.239 FT/SEC MACH NO .043646

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	925.18	793.15	694.14	555.51	397.08	347.57	278.26	185.84	93.42	70.31	56.45	47.21
KM/MEAS	.16294	.19008	.21723	.27151	.38005	.43430	.54278	.81386	1.62541	2.16527	2.70417	3.24211
MEAS/KM	6.1373	5.2606	4.6034	3.6831	2.6312	2.3025	1.8424	1.2288	.6152	.4616	.3698	.3084
BARS/MEAS	.01355	.01581	.01807	.02259	.03163	.03615	.04520	.06783	.13585	.18130	.22683	.27244
MEAS/BAR	73.7923	63.2477	55.3392	44.2673	31.6137	27.6599	22.1235	14.7423	7.3611	5.5198	4.4086	3.6709
DEGK/MEAS	.14812	.17280	.19748	.24683	.34550	.39432	.49344	.73982	1.47764	1.96843	2.45833	2.94737
MEAS/DEGK	6.7511	5.7869	5.0638	4.0514	2.8944	2.5328	2.0266	1.3517	.6708	.5130	.4068	.3393
MEAS/PSCHT	529.72552539.81144472.37587377.95607270.0691+230.3513+189.14041120.20e+4 53.20623 47.03104 38.06383 31.79561											

RADIUS 59635.000 KM ALTITUDE -165.000 KM PRESSURE 8.949615 BARS TEMPERATURE 300.355 KELVIN
-541.339 KFT 8.832584 ATM 80.968 FAHRENHEIT
TIME 2863.352 SEC VELOCITY 53.439 METER/SEC DYN P .011620 BARS
47.79586 MIN 4.5941 MB/SEC DOPPLER 3.874588E+02 CPS
.795931 HRS 175.325 FT/SEC MACH NO .042605

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	956.12	819.67	717.34	574.07	410.34	359.17	287.34	192.02	96.01	72.03	58.31	48.76
KM/MEAS	.16028	.18698	.21368	.25708	.37384	.42721	.53392	.80053	1.59898	2.13011	2.66034	3.18965
MEAS/KM	6.2393	5.3482	4.6799	3.7442	2.6749	2.3407	1.8729	1.2492	.6254	.4693	.3759	.3135
BARS/MEAS	.01378	.01608	.01838	.02297	.03217	.03677	.04597	.06898	.13814	.18435	.23004	.27702
MEAS/BAR	72.5625	62.1937	54.4171	43.5298	31.0872	27.1939	21.7553	14.4971	7.2389	5.4244	4.3457	3.6099
DEGK/MEAS	.14570	.16998	.19426	.24280	.33985	.38838	.48538	.72776	1.45361	1.93847	2.41849	2.89968
MEAS/DEGK	6.8632	5.8830	5.1478	4.1186	2.9424	2.5748	2.0602	1.3741	.6879	.5164	.4135	.3449
MEAS/PSCHT	549.90671557.10959487.51175390.07477278.71820243.91927195.2007+130.24265 65.28434 49.04462 39.30070 32.80467											

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59630.000 KM ALTITUDE -170.000 KM PRESSURE 9.386455 BARS TEMPERATURE 304.900 KELVIN
-557.743 KFT 9.263710 ATM 89.150 FAHRENHEIT
TIME 2959.664 SEC VELOCITY 52.579 METER/SEC DYN P .011620 BARS
49.32806 MIN 4.6701 MB/SEC DOPPLER 3.812194E+02 CPS
.822134 HRS 172.502 FT/SEC MACH NO .041607

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	987.55	946.62	740.92	592.94	423.81	370.36	296.97	199.31	99.66	74.99	60.19	50.33
KM/MEAS	.15770	.18397	.21024	.26278	.36783	.42034	.52534	.78767	1.57335	2.09603	2.61784	3.13878
MEAS/KM	6.3413	5.4357	4.7564	3.8054	2.7185	2.3790	1.9035	1.2696	.6356	.4771	.3820	.3186
BARS/MEAS	.01401	.01635	.01868	.02336	.03270	.03738	.04673	.07013	.14044	.18741	.23447	.28160
MEAS/BAR	71.3707	61.1722	53.5234	42.8150	30.5769	26.7525	21.3983	14.2594	7.1205	5.3358	4.2650	3.5511
DEGK/MEAS	.14335	.16725	.19113	.23889	.33439	.38213	.47758	.71607	1.43032	1.90649	2.37986	2.85344
MEAS/DEGK	6.9755	5.9792	5.2320	4.1860	2.9903	2.6159	2.0939	1.3965	.6991	.5248	.4202	.3505
MEAS/PSCHT	570.41738574.69017502.89475402.38116287.50847251.61075201.35392134.34477								67.33539	50.58291	40.53135	33.63021

RADIUS 59625.000 KM ALTITUDE -175.000 KM PRESSURE 9.837753 BARS TEMPERATURE 309.445 KELVIN
-574.147 KFT 9.709107 ATM 97.332 FAHRENHEIT
TIME 3055.548 SEC VELOCITY 51.744 METER/SEC DYN P .011620 BARS
50.92580 MIN 4.7452 MB/SEC DOPPLER 3.751695E+02 CPS
.848763 HRS 169.765 FT/SEC MACH NO .040645

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1019.52	974.01	764.89	612.11	437.51	382.94	306.55	204.70	102.85	77.39	62.11	51.93
KM/MEAS	.15519	.18105	.20691	.25861	.36200	.41358	.51702	.77520	1.54846	2.06290	2.57649	3.08923
MEAS/KM	6.4435	5.5233	4.8331	3.8668	2.7624	2.4173	1.9342	1.2900	.6458	.4846	.3881	.3237
BARS/MEAS	.01424	.01662	.01899	.02374	.03324	.03799	.04750	.07126	.14274	.19048	.23830	.28620
MEAS/BAR	70.2150	60.1618	52.6569	42.1220	30.0821	26.3197	21.0522	14.0290	7.0057	5.2498	4.1963	3.4940
DEGK/MEAS	.14109	.16459	.18810	.23510	.32909	.37607	.46948	.69610	1.37482	1.82636	2.27716	2.72722
MEAS/DEGK	7.0879	6.0756	5.3164	4.2534	3.0387	2.6591	2.1300	1.4366	.7274	.5475	.4391	.3667
MEAS/PSCHT	591.25790592.55346518.52513414.88546296.44011259.42932207.60614138.51313								69.41878	52.14489	41.78044	34.87072

RADIUS 59620.000 KM ALTITUDE -180.000 KM PRESSURE 10.303868 BARS TEMPERATURE 313.850 KELVIN
-590.551 KFT 10.169127 ATM 105.260 FAHRENHEIT
TIME 3152.958 SEC VELOCITY 50.923 METER/SEC DYN P .011652 BARS
52.54930 MIN 4.8356 MB/SEC DOPPLER 3.692162E+02 CPS
.875822 HRS 167.071 FT/SEC MACH NO .039718

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1051.99	1001.85	789.24	631.59	451.42	395.12	316.30	211.20	106.10	79.82	64.06	53.55
KM/MEAS	.15273	.17818	.20363	.25451	.35625	.40712	.50882	.76292	1.52398	2.03034	2.53588	3.04061
MEAS/KM	6.5474	5.6123	4.9110	3.9291	2.8069	2.4563	1.9653	1.3108	.6562	.4925	.3943	.3289
BARS/MEAS	.01448	.01689	.01930	.02413	.03379	.03862	.04828	.07245	.14509	.19361	.24221	.29088
MEAS/BAR	69.0779	59.2072	51.8041	41.4399	29.5951	25.8935	20.7114	13.8020	6.8925	5.1651	4.1287	3.4378
DEGK/MEAS	.13406	.15640	.17873	.22340	.31270	.35735	.44661	.66904	1.33766	1.78211	2.22584	2.66887
MEAS/DEGK	7.4594	6.3940	5.5950	4.4764	3.1979	2.7984	2.2391	1.4933	.7476	.5611	.4493	.3747
MEAS/PSCHT	712.26923510.56278534.28294427.49116305.44339267.30346213.90754142.71293								71.31811	53.71928	43.03990	35.92025

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59960.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59615.000 KM ALTITUDE -185.000 KM PRESSURE 10.785213 BARS TEMPERATURE 316.239 KELVIN
-606.955 KFT 10.644178 ATM 113.159 FAHRENHEIT
TIME 3251.930 SEC VELOCITY 50.125 METER/SEC DYN P .011652 BARS
54.19883 MIN 4.9145 MB/SEC DOPPLER 3.634279E+02 CPS
.903314 HRS 164.451 FT/SEC MACH NO .038825

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1084.98	930.12	813.96	651.39	465.55	407.49	326.19	217.80	139.40	82.30	65.04	55.20
KM/MEAS	.15034	.17539	.20044	.25052	.35068	.40075	.50085	.75096	1.50019	1.99884	2.49641	2.99336
MEAS/KM	6.6516	5.7016	4.9891	3.9916	2.8515	2.4956	1.9966	1.3316	.6666	.5003	.4006	.3341
BARS/MEAS	.01471	.01715	.01962	.02452	.03434	.03925	.04907	.07363	.14744	.19674	.24612	.29557
MEAS/BAR	67.9726	58.2599	50.9754	40.7771	29.1218	25.4795	20.3804	13.5815	6.7826	5.0829	4.0631	3.3832
DEGK/MEAS	.13196	.15335	.17593	.21990	.30781	.35175	.43962	.65917	1.31678	1.75433	2.19120	2.62739
MEAS/DEGK	7.5782	6.4958	5.6841	4.5476	3.2488	2.8429	2.2747	1.5171	.7594	.5700	.4564	.3806
MEAS/PSCHT	733.59912	628.84554	550.28035	440.28908	314.58475	275.30215	220.30648	146.97988	73.55108	55.31901	44.31309	36.98674

RADIUS 59610.000 KM ALTITUDE -190.000 KM PRESSURE 11.282073 BARS TEMPERATURE 322.627 KELVIN
-623.360 KFT 11.134540 ATM 121.059 FAHRENHEIT
TIME 3352.460 SEC VELOCITY 49.350 METER/SEC DYN P .011652 BARS
55.87444 MIN 4.9325 MB/SEC DOPPLER 3.578070E+02 CPS
.931241 HRS 161.908 FT/SEC MACH NO .037963

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1118.49	958.85	839.12	671.49	479.92	420.06	336.25	224.50	112.75	84.61	68.05	56.87
KM/MEAS	.14301	.17268	.19734	.24665	.34525	.39455	.49312	.73939	1.47709	1.96796	2.45808	2.94746
MEAS/KM	6.9961	5.7912	5.0675	4.0543	2.8964	2.5345	2.0279	1.3525	.6770	.5081	.4068	.3393
BARS/MEAS	.01495	.01744	.01993	.02492	.03489	.03988	.04985	.07481	.14979	.19988	.25004	.30028
MEAS/BAR	66.8993	57.3401	50.1706	40.1334	28.6622	25.0775	20.0589	13.3674	6.6759	5.0031	3.9994	3.3302
DEGK/MEAS	.12992	.15157	.17321	.21650	.30306	.34632	.43283	.64949	1.29820	1.72735	2.15755	2.58710
MEAS/DEGK	7.6972	6.5978	5.7733	4.6190	3.2998	2.8875	2.3104	1.5408	.7713	.5789	.4635	.3865
MEAS/PSCHT	755.26299	647.41456	563.52824	453.28739	323.86925	283.42608	226.80562	151.31163	75.81745	56.94379	45.61951	38.06993

RADIUS 59605.000 KM ALTITUDE -195.000 KM PRESSURE 11.794730 BARS TEMPERATURE 327.016 KELVIN
-639.764 KFT 11.640494 ATM 128.959 FAHRENHEIT
TIME 3454.572 SEC VELOCITY 48.596 METER/SEC DYN P .011652 BARS
57.57620 MIN 5.0707 MB/SEC DOPPLER 3.523462E+02 CPS
.959603 HRS 159.437 FT/SEC MACH NO .037132

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1152.52	988.02	864.64	691.91	494.51	432.32	346.46	231.30	116.15	87.36	70.09	58.58
KM/MEAS	.14576	.17004	.19433	.24289	.34000	.38854	.48560	.72813	1.45404	1.93809	2.42062	2.90285
MEAS/KM	6.8608	5.8809	5.1460	4.1171	2.9412	2.5737	2.0593	1.3734	.6875	.5160	.4131	.3445
BARS/MEAS	.01518	.01772	.02025	.02531	.03544	.04051	.05064	.07595	.15215	.20302	.25397	.30499
MEAS/BAR	65.8567	56.4464	49.3838	39.5080	28.2158	24.6859	19.7466	13.1594	6.5723	4.9255	3.9375	3.2788
DEGK/MEAS	.12794	.14925	.17057	.21320	.29843	.34104	.42623	.63911	1.27680	1.70114	2.12485	2.54794
MEAS/DEGK	7.8154	6.7000	5.8627	4.6905	3.3509	2.9322	2.3461	1.5647	.7832	.5878	.4706	.3925
MEAS/PSCHT	777.26142	666.27036	583.02706	466.48644	333.29713	291.67547	233.40513	155.71136	78.01728	58.59366	46.93341	39.16985

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59600.000 KM ALTITUDE -200.000 KM PRESSURE 12.323471 BARS TEMPERATURE 331.405 KELVIN
-656.168 KFT 12.162320 ATM 136.858 FAHRENHEIT
TIME 3553.249 SEC VELOCITY 47.864 METER/SEC DYN P .011652 BARS
59.30415 MIN 5.1491 MB/SEC DOPPLER 3.470391E+02 CPS
.988403 HRS 157.035 FT/SEC MACH NO .036330

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1187.00	1017.64	890.56	712.65	509.32	445.78	356.82	238.22	119.61	89.96	72.16	60.30
KM/MEAS	.14356	.16748	.19140	.23924	.33488	.38259	.47830	.71719	1.43282	1.90905	2.38460	2.85948
MEAS/KM	6.9656	5.9708	5.2246	4.1800	2.9861	2.6131	2.0908	1.3943	.6979	.5238	.4194	.3497
BARS/MEAS	.01542	.01799	.02056	.02571	.03599	.04114	.05143	.07718	.15452	.20618	.25791	.30972
MEAS/BAR	64.8433	55.5780	48.6289	38.9003	27.7819	24.3073	19.4430	12.9573	6.4715	4.8501	3.8772	3.2287
DEGK/MEAS	.12601	.14701	.16800	.20999	.29394	.33590	.41982	.62950	1.25764	1.67565	2.09306	2.50988
MEAS/DEGK	7.9359	6.8024	5.9523	4.7622	3.4021	2.9770	2.3820	1.5886	.7951	.5968	.4778	.3984
MEAS/PSCHT	799.59501685.41343599.77724479.88657342.86865300.05054240.10518160.17799								80.25062	60.26866	48.27942	40.28653

RADIUS 59595.000 KM ALTITUDE -205.000 KM PRESSURE 12.868581 BARS TEMPERATURE 335.793 KELVIN
-672.572 KFT 12.700302 ATM 144.758 FAHRENHEIT
TIME 3663.502 SEC VELOCITY 47.153 METER/SEC DYN P .011652 BARS
61.05836 MIN 5.2277 MB/SEC DOPPLER 3.418792E+02 CPS
1.017639 HRS 154.701 FT/SEC MACH NO .035555

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1222.17	1047.71	916.68	733.70	524.35	458.94	367.35	245.23	123.12	92.59	74.27	62.06
KM/MEAS	.14143	.16499	.18856	.23568	.32991	.37701	.47120	.70654	1.41160	1.88082	2.34938	2.81730
MEAS/KM	7.0707	6.0608	5.3034	4.2430	3.0312	2.6525	2.1223	1.4153	.7084	.5317	.4256	.3550
BARS/MEAS	.01566	.01827	.02088	.02610	.03655	.04177	.05223	.07837	.15690	.20935	.26187	.31447
MEAS/BAR	63.8582	54.7336	47.8902	38.3095	27.3600	23.9383	19.1479	12.7607	6.3735	4.7768	3.8187	3.1800
DEGK/MEAS	.12414	.14482	.16550	.20687	.28957	.33092	.41359	.62016	1.23902	1.65087	2.06214	2.47285
MEAS/DEGK	8.0556	6.9050	6.0421	4.8340	3.4534	3.0219	2.4179	1.6125	.8071	.6057	.4849	.4044
MEAS/PSCHT	922.26432704.84427615.77922493.48815352.58405308.55152246.90596164.71183								82.31753	61.96885	49.63956	41.41999

RADIUS 59590.000 KM ALTITUDE -210.000 KM PRESSURE 13.430349 BARS TEMPERATURE 340.182 KELVIN
-688.976 KFT 13.254724 ATM 152.658 FAHRENHEIT
TIME 3770.332 SEC VELOCITY 46.451 METER/SEC DYN P .011652 BARS
62.83887 MIN 5.3065 MB/SEC DOPPLER 3.368608E+02 CPS
1.047315 HRS 152.430 FT/SEC MACH NO .034807

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1257.78	1078.24	943.58	755.07	539.62	472.29	378.03	252.36	126.68	95.26	76.41	63.84
KM/MEAS	.13935	.16257	.18579	.23222	.32507	.37168	.46429	.69619	1.39096	1.85335	2.31511	2.77626
MEAS/KM	7.1760	6.1511	5.3824	4.3062	3.0763	2.6919	2.1538	1.4364	.7189	.5396	.4319	.3602
BARS/MEAS	.01590	.01855	.02120	.02650	.03711	.04241	.05302	.07956	.15928	.21252	.26583	.31922
MEAS/BAR	62.9001	53.9125	47.1718	37.7348	26.9497	23.5733	18.8609	12.5695	6.2782	4.7054	3.7617	3.1326
DEGK/MEAS	.12232	.14270	.16308	.20383	.28532	.32616	.40752	.61108	1.22090	1.62676	2.03207	2.43643
MEAS/DEGK	8.1736	7.0079	6.1321	4.9060	3.5048	3.0659	2.4538	1.6365	.8191	.6147	.4921	.4104
MEAS/PSCHT	945.26994724.56336634.03342507.29151362.44358317.17860253.80762169.31293								84.81807	63.69425	51.01989	42.57026

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59585.000 KM ALTITUDE -215.000 KM PRESSURE 14.009065 BARS TEMPERATURE 344.571 KELVIN
-705.381 KFT 13.825872 ATM 160.557 FAHRENHEIT
TIME 3873.745 SEC VELOCITY 45.787 METER/SEC DYN P .011652 BARS
64.54574 MIN 5.3854 MB/SEC DOPPLER 3.319782E+02 CPS
1.077429 HRS 150.220 FT/SEC MACH NO .034083

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1293.91	1109.21	970.69	775.75	555.11	485.84	388.87	259.58	130.29	97.97	78.57	65.65
KM/MEAS	.13733	.16022	.18310	.22886	.32036	.36610	.45757	.68612	1.37087	1.82662	2.28177	2.73631
MEAS/KM	7.2815	6.2415	5.4615	4.3695	3.1215	2.7315	2.1855	1.4575	.7295	.5475	.4383	.3655
BARS/MEAS	.01614	.01883	.02152	.02690	.03765	.04305	.05382	.08075	.16167	.21570	.26981	.32399
MEAS/BAR	61.9679	53.1136	46.4728	37.1757	26.5505	23.2301	18.5816	12.3835	6.1855	4.6360	3.7063	3.0865
DEGK/MEAS	.12354	.14063	.16071	.20088	.28119	.32134	.40162	.60224	1.20327	1.60330	2.00280	2.40177
MEAS/DEGK	8.2958	7.1109	6.2222	4.9781	3.5563	3.1120	2.4899	1.6605	.8311	.6237	.4993	.4164
MEAS/PSCHT	868.61242744.57119651.54027521.29698372.44748325.93201260.81034173.98140								87.15230	65.44492	52.42043	43.73737

RADIUS 59580.000 KM ALTITUDE -220.000 KM PRESSURE 14.605019 BARS TEMPERATURE 348.959 KELVIN
-721.785 KFT 14.414033 ATM 168.457 FAHRENHEIT
TIME 3988.741 SEC VELOCITY 45.132 METER/SEC DYN P .011652 BARS
66.47902 MIN 5.4646 MB/SEC DOPPLER 3.272260E+02 CPS
1.107984 HRS 148.070 FT/SEC MACH NO .033383

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1330.58	1140.64	998.19	798.75	570.82	499.59	399.87	266.92	133.96	100.72	80.77	67.48
KM/MEAS	.13537	.15793	.18048	.22559	.31578	.36037	.45102	.67632	1.35132	1.80060	2.24930	2.69743
MEAS/KM	7.3872	6.3321	5.5408	4.4329	3.1668	2.7711	2.2172	1.4786	.7400	.5554	.4446	.3707
BARS/MEAS	.01638	.01911	.02184	.02730	.03822	.04359	.05462	.08195	.16406	.21889	.27380	.32877
MEAS/BAR	61.0607	52.3360	45.7925	36.6316	26.1620	22.8902	18.3098	12.2025	6.0952	4.5684	3.6524	3.0416
DEGK/MEAS	.11862	.13662	.15841	.19801	.27717	.31675	.39588	.59363	1.18611	1.58046	1.97430	2.36764
MEAS/DEGK	8.4162	7.2141	6.3126	5.0504	3.6079	3.1571	2.5260	1.6846	.8431	.6327	.5065	.4224
MEAS/PSCHT	892.29232764.86824669.30019535.50490382.59593334.81135267.91429178.71736								89.52027	67.22090	53.84121	44.92136

RADIUS 59575.000 KM ALTITUDE -225.000 KM PRESSURE 15.218505 BARS TEMPERATURE 353.348 KELVIN
-738.189 KFT 15.019497 ATM 176.357 FAHRENHEIT
TIME 4100.325 SEC VELOCITY 44.494 METER/SEC DYN P .011652 BARS
68.33875 MIN 5.5439 MB/SEC DOPPLER 3.225991E+02 CPS
1.138979 HRS 145.976 FT/SEC MACH NO .032706

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1367.78	1172.52	1026.08	821.07	586.75	513.54	411.03	274.36	137.68	103.51	83.01	69.34
KM/MEAS	.13346	.15569	.17793	.22240	.31132	.35577	.44465	.66677	1.33228	1.77526	2.21768	2.65955
MEAS/KM	7.4931	6.4229	5.6202	4.4965	3.2122	2.8108	2.2489	1.4998	.7506	.5633	.4509	.3760
BARS/MEAS	.01652	.01939	.02216	.02770	.03878	.04433	.05542	.08315	.16646	.22209	.27779	.33356
MEAS/BAR	60.1774	51.5790	45.1302	36.1018	25.7837	22.5593	18.0451	12.0262	6.0074	4.5026	3.5998	2.9979
DEGK/MEAS	.11714	.13666	.15618	.19521	.27325	.31227	.39029	.58525	1.16940	1.55821	1.94655	2.33439
MEAS/DEGK	8.5369	7.3175	6.4031	5.1228	3.6595	3.2023	2.5622	1.7087	.8551	.6418	.5137	.4284
MEAS/PSCHT	916.31019785.45499687.31358549.91561392.88935343.81853275.11963183.52091								91.92204	69.02222	55.28226	46.12224

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59570.000 KM ALTITUDE -230.000 KM PRESSURE 15.949816 BARS TEMPERATURE 357.737 KELVIN
-754.593 KFT 15.642552 ATM 184.256 FAHRENHEIT
TIME 4213.500 SEC VELOCITY 43.872 METER/SEC DYN P .011652 BARS
70.22500 MIN 5.6234 MB/SEC DOPPLER 3.180929E+02 CPS
1.170417 HRS 143.937 FT/SEC MACH NO .032051

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1405.50	1204.86	1054.37	843.70	602.93	527.59	422.35	281.90	141.45	106.34	85.27	71.22
KM/MEAS	.13159	.15352	.17545	.21929	.30697	.35080	.43845	.65747	1.31374	1.75057	2.18668	2.62266
MEAS/KM	7.5993	6.5138	5.6998	4.5601	3.2575	2.8506	2.2808	1.5210	.7612	.5712	.4573	.3813
BARS/MEAS	.01686	.01967	.02248	.02810	.03935	.04497	.05622	.08436	.16887	.22530	.28180	.33837
MEAS/BAR	59.3172	50.8417	44.4851	35.5859	25.4153	22.2370	17.7874	11.8546	5.9217	4.4385	3.5486	2.9554
DEGK/MEAS	.11550	.13475	.15399	.19248	.26944	.30791	.38485	.57709	1.15312	1.53655	1.91951	2.30201
MEAS/DEGK	8.6578	7.4212	6.4937	5.1953	3.7114	3.2477	2.5984	1.7328	.8672	.6508	.5210	.4344
MEAS/PSCHT	340.66658806	296.33189705	259.58087554	207.52943403	148.32778352	125.99226282	92.42652188	59.39216	94.35765	70.84893	56.74363	47.34005

RADIUS 59565.000 KM ALTITUDE -235.000 KM PRESSURE 16.499248 BARS TEMPERATURE 362.125 KELVIN
-770.997 KFT 16.283492 ATM 192.156 FAHRENHEIT
TIME 4329.268 SEC VELOCITY 43.267 METER/SEC DYN P .011652 BARS
72.13780 MIN 5.7030 MB/SEC DOPPLER 3.137026E+02 CPS
1.202297 HRS 141.951 FT/SEC MACH NO .031416

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1443.76	1237.65	1083.07	865.65	619.32	542.03	433.63	289.55	145.28	109.21	87.57	73.14
KM/MEAS	.12978	.15140	.17302	.21627	.30274	.34597	.43241	.64841	1.29566	1.72652	2.15687	2.58670
MEAS/KM	7.7056	6.6050	5.7795	4.6239	3.3032	2.8905	2.3125	1.5422	.7718	.5792	.4636	.3866
BARS/MEAS	.01710	.01995	.02280	.02850	.03991	.04561	.05702	.08556	.17128	.22851	.28502	.34319
MEAS/BAR	58.4792	50.1235	43.8567	35.0832	25.0564	21.9230	17.5363	11.6873	5.8383	4.3761	3.4988	2.9139
DEGK/MEAS	.11391	.13283	.15187	.18983	.26573	.30357	.37954	.56914	1.13726	1.51544	1.89317	2.27045
MEAS/DEGK	8.7789	7.5250	6.5846	5.2680	3.7633	3.2931	2.6348	1.7570	.8793	.6599	.5282	.4404
MEAS/PSCHT	365.36203827	317.49942724	278.10245579	223.43669413	158.91153362	135.21303289	96.83513193	63.33123	96.82718	72.70107	58.22534	48.57481

RADIUS 59560.000 KM ALTITUDE -240.000 KM PRESSURE 17.167098 BARS TEMPERATURE 366.514 KELVIN
-787.402 KFT 16.942608 ATM 200.056 FAHRENHEIT
TIME 4444.633 SEC VELOCITY 42.676 METER/SEC DYN P .011652 BARS
74.07721 MIN 5.7828 MB/SEC DOPPLER 3.094241E+02 CPS
1.234620 HRS 140.015 FT/SEC MACH NO .030802

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1482.54	1270.90	1112.16	889.93	635.95	556.38	445.46	297.31	149.15	112.12	89.89	75.08
KM/MEAS	.12601	.14934	.17067	.21332	.29861	.34125	.42651	.63959	1.27805	1.70308	2.12761	2.55165
MEAS/KM	7.8121	6.6963	5.8594	4.6878	3.3488	2.9304	2.3446	1.5635	.7824	.5872	.4700	.3919
BARS/MEAS	.01734	.02023	.02312	.02891	.04047	.04626	.05783	.08677	.17370	.23174	.28984	.34802
MEAS/BAR	57.6625	49.4235	43.2443	34.5934	24.7065	21.6170	17.2916	11.5243	5.7570	4.3152	3.4501	2.8734
DEGK/MEAS	.11236	.13108	.14980	.18724	.26210	.29953	.37437	.56139	1.12180	1.49486	1.86749	2.23968
MEAS/DEGK	8.9002	7.6290	6.6756	5.3408	3.8153	3.3396	2.6712	1.7813	.8914	.6690	.5355	.4465
MEAS/PSCHT	390.39709848	334.95803742	292.87873594	234.35771424	167.64082371	146.60116297	104.34563198	69.33822	99.33066	74.57868	59.72743	49.82655

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59555.000 KM ALTITUDE -245.000 KM PRESSURE 17.853663 BARS TEMPERATURE 370.903 KELVIN
-803.806 KFT 17.620196 ATM 207.955 FAHRENHEIT
TIME 4962.597 SEC VELOCITY 42.101 METER/SEC DYN P .011652 BARS
76.04328 MIN 5.8628 MB/SEC DOPPLER 3.052531E+02 CPS
1.267388 HRS 138.127 FT/SEC MACH NO .030206

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1521.87	1304.60	1141.65	913.52	652.80	571.32	457.26	305.17	153.09	115.06	92.25	77.04
KM/MEAS	.12628	.14732	.16837	.21045	.29459	.33666	.42077	.63098	1.26088	1.68022	2.09908	2.51747
MEAS/KM	7.9188	6.7877	5.9394	4.7518	3.3945	2.9704	2.3766	1.5848	.7931	.5952	.4764	.3972
BARS/MEAS	.01759	.02052	.02345	.02931	.04104	.04691	.05864	.08799	.17613	.23497	.29388	.35286
MEAS/BAR	56.8663	48.7412	42.6473	34.1159	24.3655	21.3187	17.0530	11.3654	5.6778	4.2559	3.4027	2.8340
DEGK/MEAS	.11084	.12931	.14778	.18472	.25857	.29550	.36933	.55383	1.10672	1.47479	1.84245	2.20968
MEAS/DEGK	9.0218	7.7332	6.7667	5.4137	3.8674	3.38+1	2.7076	1.8056	.9036	.6781	.5428	.4526
MEAS/PSCHT	*15.77226870.70817761.91010609.59280435.51587381.11633304.95816203.41323101.86815									76.48179	61.24992	51.09529

RADIUS 59550.000 KM ALTITUDE -250.000 KM PRESSURE 18.559244 BARS TEMPERATURE 375.292 KELVIN
-820.210 KFT 18.316550 ATM 215.855 FAHRENHEIT
TIME 4682.163 SEC VELOCITY 41.540 METER/SEC DYN P .011652 BARS
78.03606 MIN 5.9430 MB/SEC DOPPLER 3.011857E+02 CPS
1.300601 HRS 136.287 FT/SEC MACH NO .029629

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1561.72	1338.76	1171.54	937.43	669.88	586.27	469.22	313.14	157.07	118.05	94.64	79.04
KM/MEAS	.12460	.14536	.16612	.20764	.29067	.33217	.41517	.62258	1.24413	1.65792	2.07126	2.48414
MEAS/KM	8.0257	6.8794	6.0196	4.8160	3.4404	3.0105	2.4086	1.6062	.8038	.6032	.4828	.4026
BARS/MEAS	.01783	.02080	.02377	.02972	.04161	.04756	.05945	.08920	.17856	.23821	.29793	.35772
MEAS/BAR	56.0900	48.0758	42.0651	33.6502	24.0332	21.0278	16.8204	11.2104	5.6005	4.1980	3.3565	2.7955
DEGK/MEAS	.10937	.12759	.14581	.18226	.25513	.29156	.36441	.54647	1.09202	1.45522	1.81802	2.18042
MEAS/DEGK	9.1436	7.8376	6.8581	5.4868	3.9195	3.4298	2.7441	1.8299	.9157	.6872	.5500	.4586
MEAS/PSCHT	*41.48809892.75031781.19697625.02228446.53692390.76024312.67288208.55637104.43971									78.41046	62.79285	52.38107

RADIUS 59545.000 KM ALTITUDE -255.000 KM PRESSURE 19.284143 BARS TEMPERATURE 379.680 KELVIN
-836.614 KFT 19.031969 ATM 223.754 FAHRENHEIT
TIME 4803.335 SEC VELOCITY 40.993 METER/SEC DYN P .011652 BARS
80.05559 MIN 6.0234 MB/SEC DOPPLER 2.972182E+02 CPS
1.334260 HRS 134.491 FT/SEC MACH NO .029069

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1602.11	1373.38	1201.83	961.67	687.19	601.42	481.33	321.22	161.11	121.08	97.07	81.06
KM/MEAS	.12296	.14345	.16394	.20491	.28684	.32780	.40971	.61439	1.22779	1.63617	2.04411	2.45161
MEAS/KM	8.1328	6.9712	6.0999	4.8802	3.4862	3.0506	2.4408	1.6276	.8145	.6112	.4892	.4079
BARS/MEAS	.01807	.02109	.02410	.03012	.04218	.04821	.06026	.09042	.18099	.24146	.30199	.36258
MEAS/BAR	55.3328	47.4258	41.4973	33.1960	23.7083	20.7441	16.5934	11.0592	5.5251	4.1415	3.3114	2.7580
DEGK/MEAS	.10793	.12591	.14389	.17986	.25177	.28772	.35962	.53928	1.07768	1.43613	1.79419	2.15187
MEAS/DEGK	9.2656	7.9422	6.9496	5.5600	3.9718	3.4756	2.7807	1.8543	.9279	.6963	.5574	.4647
MEAS/PSCHT	*67.54509915.08487800.73971640.65647457.70419400.53130320.48996213.76774107.04539									80.36471	64.35626	53.68391

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59540.000 KM ALTITUDE -260.000 KM PRESSURE 20.028660 BARS TEMPERATURE 384.069 KELVIN
-853.018 KFT 19.766751 ATM 231.654 FAHRENHEIT
TIME 4926.116 SEC VELOCITY 40.459 METER/SEC DYN P .011676 BARS
82.10193 MIN 6.1164 MB/SEC DOPPLER 2.933470E+02 CPS
1.368365 HRS 132.740 FT/SEC MACH NO .028526

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1643.04	1408.46	1232.53	985.22	704.73	616.76	493.61	329.41	165.20	124.15	99.52	83.10
KM/MEAS	.12136	.14158	.16180	.20224	.28311	.32354	.40438	.60640	1.21185	1.61494	2.01762	2.41987
MEAS/KM	8.2401	7.0631	6.1804	4.9446	3.5322	3.0909	2.4729	1.6491	.8252	.6192	.4956	.4132
BARS/MEAS	.01832	.02137	.02442	.03053	.04275	.04886	.06108	.09164	.18344	.24471	.30605	.36746
MEAS/BAR	54.5940	46.7936	40.9433	32.7529	23.3924	20.4672	16.3720	10.9118	5.4515	4.0864	3.2674	2.7214
DEGK/MEAS	.10652	.12427	.14202	.17752	.24849	.28398	.35494	.53226	1.06368	1.41750	1.77094	2.12401
MEAS/DEGK	9.3879	8.0470	7.0413	5.6333	4.0242	3.5214	2.8174	1.8788	.9401	.7055	.5647	.4708
MEAS/PSCHT	*93.94377	937.71231	820.53871	636.49567	469.01789	410.43108	328.40954	219.04745	109.68523	82.34459	65.94016	55.00382

RADIUS 59535.000 KM ALTITUDE -265.000 KM PRESSURE 20.793101 BARS TEMPERATURE 388.458 KELVIN
-869.423 KFT 20.521195 ATM 239.554 FAHRENHEIT
TIME 5051.507 SEC VELOCITY 39.938 METER/SEC DYN P .011676 BARS
84.17512 MIN 6.1972 MB/SEC DOPPLER 2.895688E+02 CPS
1.402919 HRS 131.030 FT/SEC MACH NO .027999

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1684.50	1444.00	1263.63	1011.10	722.50	632.31	506.05	337.70	169.35	127.26	102.01	85.18
KM/MEAS	.11980	.13975	.15972	.19964	.27945	.31937	.39917	.59860	1.19628	1.59422	1.99175	2.38888
MEAS/KM	8.3476	7.1552	6.2610	5.0091	3.5783	3.1312	2.5052	1.6706	.8359	.6273	.5021	.4186
BARS/MEAS	.01856	.02166	.02475	.03094	.04332	.04951	.06190	.09287	.18588	.24798	.31013	.37235
MEAS/BAR	53.8729	46.1756	40.4026	32.3203	23.0835	20.1970	16.1559	10.7678	5.3797	4.0326	3.2244	2.6856
DEGK/MEAS	.10515	.12267	.14019	.17523	.24530	.28032	.35037	.52542	1.05002	1.39931	1.74824	2.09681
MEAS/DEGK	9.5103	8.1519	7.1331	5.7068	4.0767	3.5673	2.8541	1.9032	.9524	.7146	.5720	.4769
MEAS/PSCHT	*20.68465	960.53305	840.59436	672.54018	480.47825	420.45839	336.43178	224.39560	112.35929	84.35014	67.54459	56.34085

RADIUS 59530.000 KM ALTITUDE -270.000 KM PRESSURE 21.577771 BARS TEMPERATURE 392.846 KELVIN
-885.827 KFT 21.295605 ATM 247.453 FAHRENHEIT
TIME 5175.512 SEC VELOCITY 39.429 METER/SEC DYN P .011676 BARS
86.27521 MIN 6.2783 MB/SEC DOPPLER 2.858802E+02 CPS
1.437920 HRS 129.361 FT/SEC MACH NO .027488

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1726.50	1480.00	1295.13	1036.30	740.50	648.06	518.65	346.10	173.55	130.41	104.53	87.28
KM/MEAS	.11827	.13798	.15769	.19710	.27591	.31531	.39409	.59099	1.18109	1.57399	1.96650	2.35862
MEAS/KM	8.4552	7.2475	6.3418	5.0737	3.6244	3.1715	2.5375	1.6921	.8467	.6353	.5085	.4240
BARS/MEAS	.01881	.02194	.02508	.03135	.04389	.05017	.06272	.09410	.18834	.25125	.31422	.37726
MEAS/BAR	53.1690	45.5723	39.8747	31.8981	22.7820	19.9333	15.9450	10.6273	5.3096	3.9801	3.1825	2.6507
DEGK/MEAS	.10381	.12111	.13841	.17300	.24217	.27676	.34591	.51873	1.03668	1.38155	1.72607	2.07025
MEAS/DEGK	9.6330	8.2571	7.2251	5.7804	4.1293	3.6133	2.8909	1.9276	.9646	.7238	.5794	.4830
MEAS/PSCHT	*47.76822	983.84754	860.90703	688.79031	492.08547	430.61521	344.55683	229.81229	115.06763	86.38138	69.16958	57.69501

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59525.000 KM ALTITUDE -275.000 KM PRESSURE 22.382977 BARS TEMPERATURE 397.235 KELVIN
-902.231 KFT 22.090261 ATM 255.353 FAHRENHEIT
TIME 5304.135 SEC VELOCITY 38.932 METER/SEC DYN P .011676 BARS
88.4022A MIN 6.3594 MB/SEC DOPPLER 2.822782E+02 CPS
1.473371 HRS 127.731 FT/SEC MACH NO .026991

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1769.04	1516.47	1327.03	1061.83	758.73	664.32	531.41	354.61	177.80	133.60	107.06	89.40
KM/MEAS	.11678	.13624	.15570	.19461	.27243	.31134	.38913	.58355	1.16625	1.55423	1.94184	2.32906
MEAS/KM	8.5631	7.3400	6.4226	5.1384	3.6705	3.2120	2.5698	1.7136	.8575	.6434	.5150	.4294
BARS/MEAS	.01905	.02223	.02541	.03176	.04447	.05082	.06354	.09533	.19080	.25453	.31832	.38217
MEAS/BAR	52.4816	44.9831	39.3593	31.4858	22.4875	19.6757	15.7390	10.4900	5.2411	3.9288	3.1415	2.6166
DEGK/MEAS	.10250	.11958	.13666	.17082	.23912	.27327	.34156	.51221	1.02366	1.36421	1.70442	2.04431
MEAS/DEGK	9.7559	8.3624	7.3173	5.8541	4.1819	3.6594	2.9278	1.9523	.9769	.7330	.5867	.4892
MEAS/PSCHT	*75.19500	*67.35621	881.47711	705.24636	503.83979	440.90023	352.78484	235.29762	117.81028	88.43837	70.81517	59.06633

RADIUS 59520.000 KM ALTITUDE -280.000 KM PRESSURE 23.209027 BARS TEMPERATURE 401.624 KELVIN
-918.635 KFT 22.905529 ATM 263.253 FAHRENHEIT
TIME 5433.377 SEC VELOCITY 38.447 METER/SEC DYN P .011676 BARS
90.55628 MIN 6.4408 MB/SEC DOPPLER 2.787598E+02 CPS
1.509271 HRS 126.139 FT/SEC MACH NO .026509

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1812.13	1553.39	1359.34	1087.68	777.20	680.17	544.34	363.23	182.11	136.83	109.67	91.56
KM/MEAS	.11532	.13454	.15376	.19219	.26904	.30746	.38429	.57629	1.15175	1.53493	1.91774	2.30019
MEAS/KM	8.6712	7.4326	6.5037	5.2032	3.7169	3.2525	2.6022	1.7352	.8682	.6515	.5214	.4347
BARS/MEAS	.01930	.02252	.02574	.03217	.04504	.05148	.06436	.09656	.19327	.25781	.32243	.38710
MEAS/BAR	51.8103	44.4077	38.8558	31.0831	22.2001	19.4241	15.5378	10.3560	5.1742	3.8798	3.1015	2.5833
DEGK/MEAS	.10122	.11809	.13496	.15869	.23615	.26987	.33730	.50583	1.01093	1.34727	1.68327	2.01896
MEAS/DEGK	9.8790	8.4679	7.4096	5.9280	4.2347	3.7055	2.9647	1.9769	.9892	.7422	.5941	.4953
MEAS/PSCHT	*82.96548	*71.15947	902.30496	721.90863	515.74140	451.31413	361.11596	240.85169	120.58730	90.52113	72.46138	60.45484

RADIUS 59515.000 KM ALTITUDE -285.000 KM PRESSURE 24.056230 BARS TEMPERATURE 406.012 KELVIN
-935.039 KFT 23.741654 ATM 271.152 FAHRENHEIT
TIME 5564.241 SEC VELOCITY 37.973 METER/SEC DYN P .011676 BARS
92.73735 MIN 6.5223 MB/SEC DOPPLER 2.753222E+02 CPS
1.545622 HRS 124.584 FT/SEC MACH NO .026040

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1855.75	1590.78	1392.06	1113.85	795.89	696.53	557.42	371.95	186.47	140.11	112.28	93.74
KM/MEAS	.11390	.13288	.15186	.18982	.26572	.30367	.37955	.56919	1.13758	1.51607	1.89420	2.27197
MEAS/KM	8.7794	7.5254	6.5849	5.2681	3.7633	3.2930	2.6347	1.7569	.8791	.6596	.5279	.4401
BARS/MEAS	.01955	.02281	.02607	.03258	.04562	.05214	.06518	.09780	.19574	.26111	.32654	.39204
MEAS/BAR	51.1543	43.8455	38.3639	30.6897	21.9191	19.1733	15.3412	10.2250	5.1088	3.8298	3.0624	2.5508
DEGK/MEAS	.09998	.11664	.13330	.15661	.23324	.26654	.33315	.49960	.99850	1.33071	1.66261	1.99420
MEAS/DEGK	10.0023	8.5736	7.5021	6.0019	4.2875	3.7517	3.0017	2.0016	1.0015	.7515	.6015	.5015
MEAS/PSCHT	*81.38015	*65.25775	923.39095	738.77742	527.79052	461.85711	369.55033	246.47460	123.39874	92.62970	74.16824	61.86055

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59510.000 KM ALTITUDE -290.000 KM PRESSURE 24.924899 BARS TEMPERATURE 410.401 KELVIN
-951.444 KFT 24.598962 ATM 279.052 FAHRENHEIT
TIME 5695.730 SEC VELOCITY 37.510 METER/SEC DYN P .011676 BARS
94.94550 MIN 6.6040 MB/SEC DOPPLER 2.719628E+02 CPS
1.582425 HRS 123.063 FT/SEC MACH NO .025584

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1899.91	1528.64	1425.18	1140.35	814.82	713.09	570.07	380.78	190.89	143.42	114.93	95.95
KM/MEAS	.11251	.13126	.15001	.18751	.26248	.29997	.37492	.56226	1.12374	1.49763	1.87118	2.24439
MEAS/KM	8.8878	7.6183	6.6662	5.3332	3.8098	3.3337	2.6672	1.7785	.8899	.6677	.5344	.4456
BARS/MEAS	.01980	.02310	.02640	.03300	.04620	.05280	.06601	.09904	.19822	.26441	.33067	.39699
MEAS/BAR	50.5133	43.2961	37.8832	30.3052	21.6445	18.9381	15.1490	10.0970	5.0450	3.7820	3.0242	2.5190
DEGK/MEAS	.09875	.11521	.13157	.15456	.23039	.26329	.32909	.49351	.98635	1.31453	1.64241	1.96999
MEAS/DEGK	10.1258	8.6795	7.5947	6.0761	4.3404	3.7981	3.0387	2.0263	1.0138	.7607	.6089	.5076
MEAS/PSCHT	*59.53930	*79.65147	944.73545	755.85302	539.98737	472.52935	378.08811	252.16644	126.24465	94.76413	75.87377	63.28350

RADIUS 59505.000 KM ALTITUDE -295.000 KM PRESSURE 25.815344 BARS TEMPERATURE 414.790 KELVIN
-967.848 KFT 25.477764 ATM 286.952 FAHRENHEIT
TIME 5830.848 SEC VELOCITY 37.057 METER/SEC DYN P .011676 BARS
97.18079 MIN 6.6858 MB/SEC DOPPLER 2.686788E+02 CPS
1.619680 HRS 121.577 FT/SEC MACH NO .025141

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1944.62	1566.96	1458.71	1167.17	833.95	729.36	584.08	389.72	195.36	146.77	117.62	98.18
KM/MEAS	.11116	.12968	.14820	.18524	.25932	.29635	.37040	.55548	1.11020	1.47961	1.84866	2.21743
MEAS/KM	8.9964	7.7114	6.7476	5.3983	3.8563	3.3744	2.6998	1.8003	.9007	.6759	.5409	.4510
BARS/MEAS	.02005	.02339	.02673	.03341	.04678	.05347	.06684	.10028	.20070	.26772	.33481	.40195
MEAS/BAR	49.8858	42.7591	37.4134	29.9293	21.3761	18.7033	14.9612	9.9719	4.9825	3.7352	2.9866	2.4879
DEGK/MEAS	.09757	.11382	.13008	.16259	.22761	.26012	.32511	.48756	.97447	1.29871	1.62266	1.94632
MEAS/DEGK	10.2496	8.7855	7.6875	6.1503	4.3935	3.8444	3.0758	2.0510	1.0262	.7700	.6163	.5138
MEAS/PSCHT	*88.34401	*04.34104	965.33882	773.13571	552.33214	483.33101	386.72944	257.92731	129.12507	96.92444	77.60402	64.72370

RADIUS 59500.000 KM ALTITUDE -300.000 KM PRESSURE 26.727880 BARS TEMPERATURE 419.178 KELVIN
-984.252 KFT 26.378367 ATM 294.851 FAHRENHEIT
TIME 5966.596 SEC VELOCITY 36.614 METER/SEC DYN P .011676 BARS
99.44326 MIN 6.7678 MB/SEC DOPPLER 2.654680E+02 CPS
1.657388 HRS 120.124 FT/SEC MACH NO .024710

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	1989.87	1705.74	1492.65	1194.32	853.37	746.32	597.66	398.77	199.89	150.16	120.33	100.44
KM/MEAS	.10983	.12813	.14643	.18303	.25622	.29281	.36598	.54885	1.09697	1.46198	1.82868	2.19106
MEAS/KM	9.1052	7.8046	6.8292	5.4636	3.9029	3.4152	2.7324	1.8220	.9116	.6840	.5474	.4564
BARS/MEAS	.02029	.02368	.02706	.03383	.04735	.05413	.06767	.10153	.20319	.27104	.33895	.40693
MEAS/BAR	49.2742	42.2341	36.9540	29.5619	21.1137	18.4737	14.7775	9.8496	4.9215	3.6895	2.9503	2.4575
DEGK/MEAS	.09540	.11246	.12853	.16065	.22489	.25701	.32123	.48174	.96285	1.28324	1.60335	1.92317
MEAS/DEGK	10.3735	8.8918	7.7805	6.2246	4.4465	3.8919	3.1130	2.0758	1.0386	.7793	.6237	.5200
MEAS/PSCHT	*17.49415	*29.32688	988.20142	790.62578	564.82503	494.26230	395.47446	263.75732	132.04006	99.11068	79.35301	66.18119

SURVIVABLE SATURN PROBE TASK 4 DESCENT RUNS
JPL MONOGRAPH SATURN NOMINAL ATMOSPHERE
BALLISTIC COEFFICIENT = .700, INITIAL TIME = 0. SECONDS AT 59900.000 KM RADIUS

BAL. COEF. 0.65/0.70/1.50 SEP 30 BARS

RADIUS 59495.000 KM ALTITUDE -305.000 KM PRESSURE 27.662823 BARS TEMPERATURE 423.567 KELVIN
-1000.656 KFT 27.301084 ATM 302.751 FAHRENHEIT
TIME 6103.977 SEC VELOCITY 36.181 METER/SEC DYN P .011675 BARS
101.73296 MIN 6.8500 MB/SEC DOPPLER 2.623278E+02 CPS
1.695549 HRS 118.704 FT/SEC MACH NO .024291

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	2035.66	1744.99	1526.99	1221.80	873.00	764.00	611.40	407.93	204.47	153.60	123.06	102.73
KM/MEAS	.10853	.12661	.14470	.18087	.25319	.28935	.36165	.54236	1.08402	1.44475	1.80516	2.16626
MEAS/KM	9.2142	7.8980	6.9109	5.5290	3.9495	3.4561	2.7651	1.8438	.9225	.6922	.5540	.4618
BARS/MEAS	.02054	.02397	.02739	.03424	.04795	.05480	.06850	.10276	.20569	.27437	.34311	.41191
MEAS/BAR	48.6751	41.7206	36.5047	29.2025	20.8571	18.2492	14.5981	9.7239	4.8618	3.6447	2.9145	2.4277
DEGK/MEAS	.09526	.11113	.12701	.15875	.22223	.25397	.31744	.47605	.95149	1.26811	1.58446	1.90053
MEAS/DEGK	10.4976	8.9982	7.8736	6.2991	4.4998	3.9375	3.1502	2.1006	1.0510	.7886	.6311	.5262
MEAS/PSCHT	*46.99041*	54.60938*	10.32361808	.32352577	.46627505	.32337404	.32331269	.65654134	.98966101	1.32267	81.12276	67.65598

RADIUS 59490.000 KM ALTITUDE -310.000 KM PRESSURE 28.620486 BARS TEMPERATURE 427.956 KELVIN
-1017.060 KFT 28.246226 ATM 310.651 FAHRENHEIT
TIME 6242.995 SEC VELOCITY 35.757 METER/SEC DYN P .011676 BARS
104.04992 MIN 6.9323 MB/SEC DOPPLER 2.592560E+02 CPS
1.734165 HRS 117.314 FT/SEC MACH NO .023883

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	2082.00	1784.71	1561.75	1249.60	892.86	781.37	625.30	417.20	209.10	157.07	125.86	105.05
KM/MEAS	.10726	.12513	.14300	.17875	.25023	.28596	.35742	.53602	1.07136	1.42766	1.78410	2.14003
MEAS/KM	9.3233	7.9915	6.9928	5.5945	3.9964	3.4970	2.7978	1.8656	.9334	.7003	.5605	.4673
BARS/MEAS	.02079	.02426	.02773	.03466	.04853	.05546	.06934	.10403	.20819	.27770	.34728	.41691
MEAS/BAR	48.0891	41.2183	36.0653	28.8510	20.6061	18.0236	14.4224	9.6129	4.8034	3.6010	2.8796	2.3986
DEGK/MEAS	.09414	.10983	.12552	.15689	.21963	.25100	.31372	.47048	.94037	1.25331	1.56597	1.87838
MEAS/DEGK	10.6220	9.1048	7.9668	6.3737	4.5530	3.9841	3.1875	2.1255	1.0634	.7979	.6386	.5324
MEAS/PSCHT	*76.83325*	80.18896*	32.70573826	.22921590	.25604516	.51442413	.27614275	.62508137	.97392103	.55106	82.91331	69.14810

RADIUS 59485.000 KM ALTITUDE -315.000 KM PRESSURE 29.601195 BARS TEMPERATURE 432.345 KELVIN
-1033.465 KFT 29.214108 ATM 318.550 FAHRENHEIT
TIME 6383.651 SEC VELOCITY 35.343 METER/SEC DYN P .011676 BARS
106.39419 MIN 7.0148 MB/SEC DOPPLER 2.562505E+02 CPS
1.773237 HRS 115.954 FT/SEC MACH NO .023485

INSTRUMENTS	TEMP	PRESS	TEMP	PRESS	ACCEL	ACCEL	ACCEL	ACCEL	M SPEC	M SPEC	M SPEC	M SPEC
NO OF MEAS	2128.88	1824.90	1596.91	1277.73	912.95	798.36	639.37	425.58	213.79	160.59	128.67	107.39
KM/MEAS	.10601	.12368	.14135	.17668	.24733	.28255	.35328	.52981	1.05897	1.41138	1.76350	2.11533
MEAS/KM	9.4326	8.0853	7.0748	5.6601	4.0432	3.5380	2.8306	1.8875	.9443	.7085	.5671	.4727
BARS/MEAS	.02105	.02455	.02806	.03508	.04911	.05613	.07017	.10526	.21069	.28104	.35145	.42192
MEAS/BAR	47.5158	40.7269	35.6353	28.5071	20.3605	17.8147	14.2503	9.4984	4.7462	3.5582	2.8453	2.3701
DEGK/MEAS	.09305	.10856	.12407	.15508	.21709	.24809	.31009	.46504	.92950	1.23882	1.54789	1.85671
MEAS/DEGK	10.7465	9.2115	8.0602	6.4485	4.6064	4.0308	3.2249	2.1504	1.0759	.8072	.6460	.5386
MEAS/PSCHT	*07.02315*	06.06600*	55.34814844	.34313603	.19454527	.83551422	.33309281	.66303140	.99288105	.32528	84.72468	70.65757

APPENDIX M

PROPULSION SUBSYSTEM ANALYSIS AND DEFINITION

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and
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June 19, 1972

PROPULSION SUBSYSTEM ANALYSIS AND DEFINITION (NOMINAL JUPITER PROBE)

The data presented in this appendix were prepared early in this program and are presented here largely unchanged. The data in Volumes I and II include later iterations of design, in some cases, and varies with data in this appendix.

The selected propulsion systems were studied in depth to evolve more accurate definitions of their characteristics. Neither the solid motor nor the cold gas systems exist in their entirety as flight-qualified items that will exactly satisfy the Jupiter probe propulsion requirements, but the design of suitable systems based on existing technology is not an enormous task.

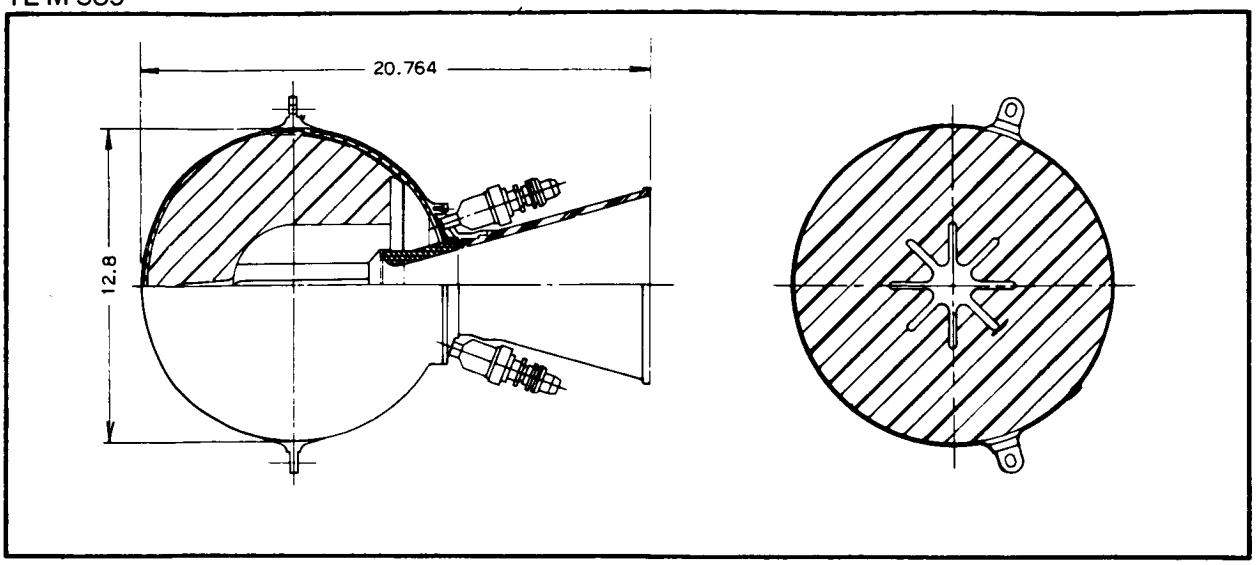
In the case of the solid motor, sizes both larger and smaller than the size (total impulse) required for this application have been developed and flight-qualified so that a new design may be developed by interpolation rather than extrapolation. Any one of the several major solid motor manufacturers in this country is capable of developing the required motor. The principal characteristics of the proposed motor are discussed herein.

The situation with regard to the cold gas system is slightly different in that it would consist of an assembly of individual components, the majority of which already exist in a flight-qualified status. Very likely, the only component to be fabricated specifically for this application would be the gas storage vessel, and even this exists in sizes very close to that required. Identification of specific candidate components for the system is included in the discussion herein.

A. SOLID PROPELLANT MOTOR

1. General Configuration

The general configuration of the motor is anticipated to be spherical, but with two partially submerged nozzles instead of the usual one to predude plume impingement on the spacecraft after probe separation. Except for the two nozzles, the motor will resemble a scaled-down version of the Thiokol TE-M-385 motor shown in Fig-M-1. It has a high strength titanium alloy case containing a bonded TL-L-305 liner (insulator) and a TP-L-3014A composite propellant grain of an 8-point star configuration. The nozzle is of phenolic construction with a graphite throat insert; a screw-in igniter near the nozzle provides propellant ignition.



CASE	
Material	Titanium Alloy 6Al4V
Strength, Min. Ultimate, psi	165,000
Strength, Min. Yield, psi	155,000
Pressure, Hydrostatic Test, psi	1,430
Nominal Thickness, in.	0.04
NOZZLE	
Material, Body	Vitreous Silica Phenolic
Material, Throat Insert	CGW Graphite
Area, Throat, $in.^2$	1.86
Ratio, Expansion	23:1
LINER	TL-L-305
IGNITER	
Type and Designation	PYROGEN TE-P-386
Minimum Firing Current, amps	4
Circuit Resistance, ohms	1.00 + 0.20
No. of Squibs/Igniter	1
CURRENT STATUS	Production

PROPELLANT	
Designation	TP-L-3014A
Web, in.	3.79
Density, Loading, Volumetric, %	83.5
MOTOR PERFORMANCE	
Time, Action, sec	5.7
Time, Ignition Delay, sec	0.022
Pressure, Chamber, Avg, psia	790
Impulse, Total, lbf-sec	14,000
Thrust, Avg. Action Time, lbf	2,150
WEIGHTS, lbm	
Total, Loaded	67.4
Propellant	55.4
Total, Inert	11.84
Mass Ratio	0.823
TEMPERATURE LIMITS, °F	
Operation	-20 to 180
Storage	10 to 160

Figure M-1 Thiokol TE-M-385 Motor

2. Propellant

The specific propellant to be used in the probe motor will be determined at a later date, dependent upon the selection of the supplier for the solid motor assembly. Each of the major solid motor manufacturers has his own collection of proprietary propellant formulations from which to choose, several of which will probably provide the required performance. The specific one selected as baseline for this study is a Thiokol modified TP-H-3062 propellant that contains 70% ammonium perchlorate and 16% aluminum in a CTPB binder. It has good physical characteristics, a very high specific impulse (principally the result of the high percentage of aluminum), and a relatively low burning rate that permits operation at a relatively low thrust level. It has a normal storage temperature range of 272 to 322°K (20 to 110°F) and a normal operating range of 283 to 311°K (40 to 90°F). The chamber pressure (and thrust) increase only 0.1% per °F temperature increase, while the burning time decreases a proportionate amount. The delivered total impulse changes only 0.003% per °K (0.005% per °F) temperature change, so that it is possible for the manufacturer to guarantee a 3-σ variation in total impulse of only ±0.75% from nominal. This degree of total impulse control is believed to be adequate for the Jupiter probe application.

The principal disadvantage of the propellant is the large percentage of solids in its exhaust products, leading to a plume impingement problem in some situations. More detailed propellant characteristics are presented in Figure M-2.

3. Motor Size

If the quantity of propellant consumed in accelerating a mass is negligible relative to the mass being accelerated, the total impulse required may be approximated by

$$Ft = \frac{W_I \Delta V}{g} = I_{sp} W_P = \frac{V_e}{g} W_P \text{ lbf-sec, or} \qquad [M-1]$$

$$\frac{W_P}{W_I} = \frac{\Delta V}{V_e},$$

Designation: Modified TP-H-3062

Composition: CTPB/AP/AL Composite

70% AP
16% AL

Characteristic Exhaust Velocity, C*, 1510 m/sec (5015 fps)

Burn Rate Equation at 70°F, $\left[0.207 \left(P_c / 500\right)^{0.34}\right]$

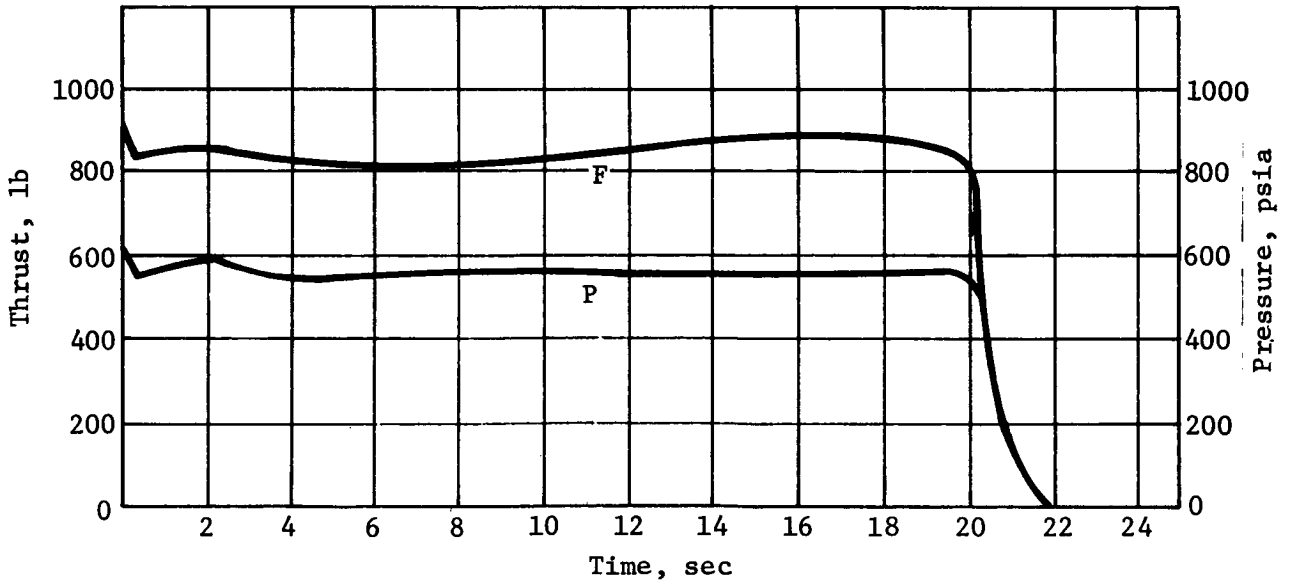
Density, 1740 kg/m^3 (0.0628 lbm/in.^{3})

Ratio of Specific Heats, 1.16

Temperature Sensitivity Coefficient, π_K, %/°F, 1.10

Specific Impulse, I_{sp}, 2820 N sec/kg (287 sec)

Typical F/t Performance



TE-M-345-12 Motor, TP-G-3129 Propellant

Figure M-2 Proposed Jupiter Probe Propellant

where

F = thrust, lbf

t = action time, sec

W_I = mass being accelerated (initial mass), lbm

W_p = quantity of propellant consumed, lbm

I_{sp} = propulsion system specific impulse, sec

Ve = propulsion system effective exhaust velocity, fps

ΔV = velocity increase, fps

If the quantity of propellant consumed is not negligible, it is necessary to use an integral solution of Newton's law based on a constant rate of propellant consumption yielding the following expression for the propellant consumed:

$$\frac{W_P}{W_I} = \frac{W_I / W_F}{W_I / W_F}^{-1} \qquad \text{[M-2]}$$

where

$$\frac{W_I}{W_F} = \log^{-1} \frac{\Delta V}{2.303\ Ve}$$

Since the difference between W_P / W_I as computed from Equations [M-1] and [M-2] is usually small for typical spacecraft propulsion systems, it is possible to provide a very accurate graphical solution to Equation [M-2] without the need to resort to logarithmic tables. Figure M-3, a plot of the difference between Equations [M-1] and [M-2], provides such a solution. Once the spacecraft ΔV and propellant I_{sp} are specified, $\Delta V/Ve$ may be computed, $\left(\Delta V/Ve - W_P/W_I\right)$, read from the graph, and W_P/W_I obtained by simple subtraction.

The specific motor to be used on the Jupiter probe will require 12.3K° (27.1 lbm) of propellant, assuming a specific impules of 2820 N sec/kg (287 sec). (This value has been achieved in motors of similar design with TP-H-3062 propellant.) Referring to Figure M-1, for a ΔV of 221 m/sec (725 fps) and a resulting probe-delta-velocity to rocket-motor-effective-exhaust velocity ratio:

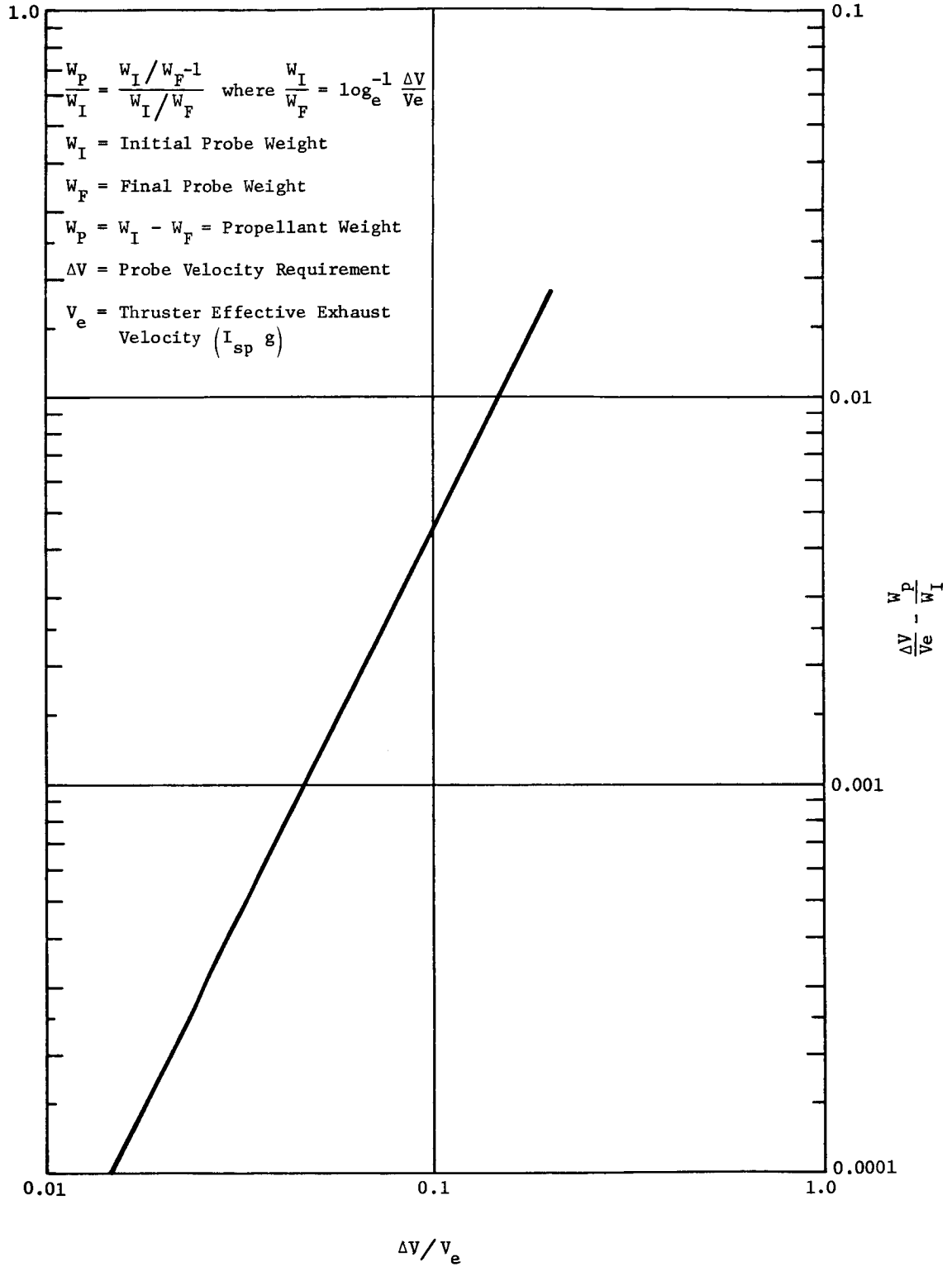


Figure M-3 Probe Propellant Requirements

$$\frac{\Delta V}{V_e} = \frac{221(3.28)}{287(32.2)} = 0.0785,$$

then

$$\frac{W_p}{W_I} = 0.0757,$$

and

W_p (propellant weight) = 11.3 kg (25 lbm) for a probe having an initial weight $\left(W_I\right)$ of 149 kg (330 lbm).

However, because of the fact that each nozzle is canted 22½° from the resultant thrust axis, the net thrust is only 92.4% of the gross thrust, and the total propellant required is 12.3 kg (27.1 lbm) instead of 11.3 kg (25 lbm). This still compares fairly closely with the first cut approximation of 11.3 kg (26 lbm) which used a cruder estimate of the required total impulse, and did not take into account the canted nozzles.

With the propellant load known, the approximate size of the motor (diameter) is also fixed. Using Thiokol data (Fig. M-4), it will be seen that a motor 10 in. in diameter is required to contain the 12.3 kg (27.1 lbm) propellant load in the proposed 8-point star configuration. Further, assuming a burning rate of $\sim$ 0.79 cm/sec (0.2 m/sec) (Fig. M-5), the motor burn time will be $\sim$ 15 sec; therefore, the net motor thrust is predicted to be

$$\frac{287 \times 25}{15} \quad 2135 \text{ N (480 lbf)},$$

Providing a probe acceleration slightly more than 1.5 g. This level of thrust and acceleration appear to be perfectly acceptable to the probe, so there appears to be no reason for considering other alternatives. If this acceleration level proved to be unacceptable, and entirely different motor/propellant grain configuration might have to be developed.

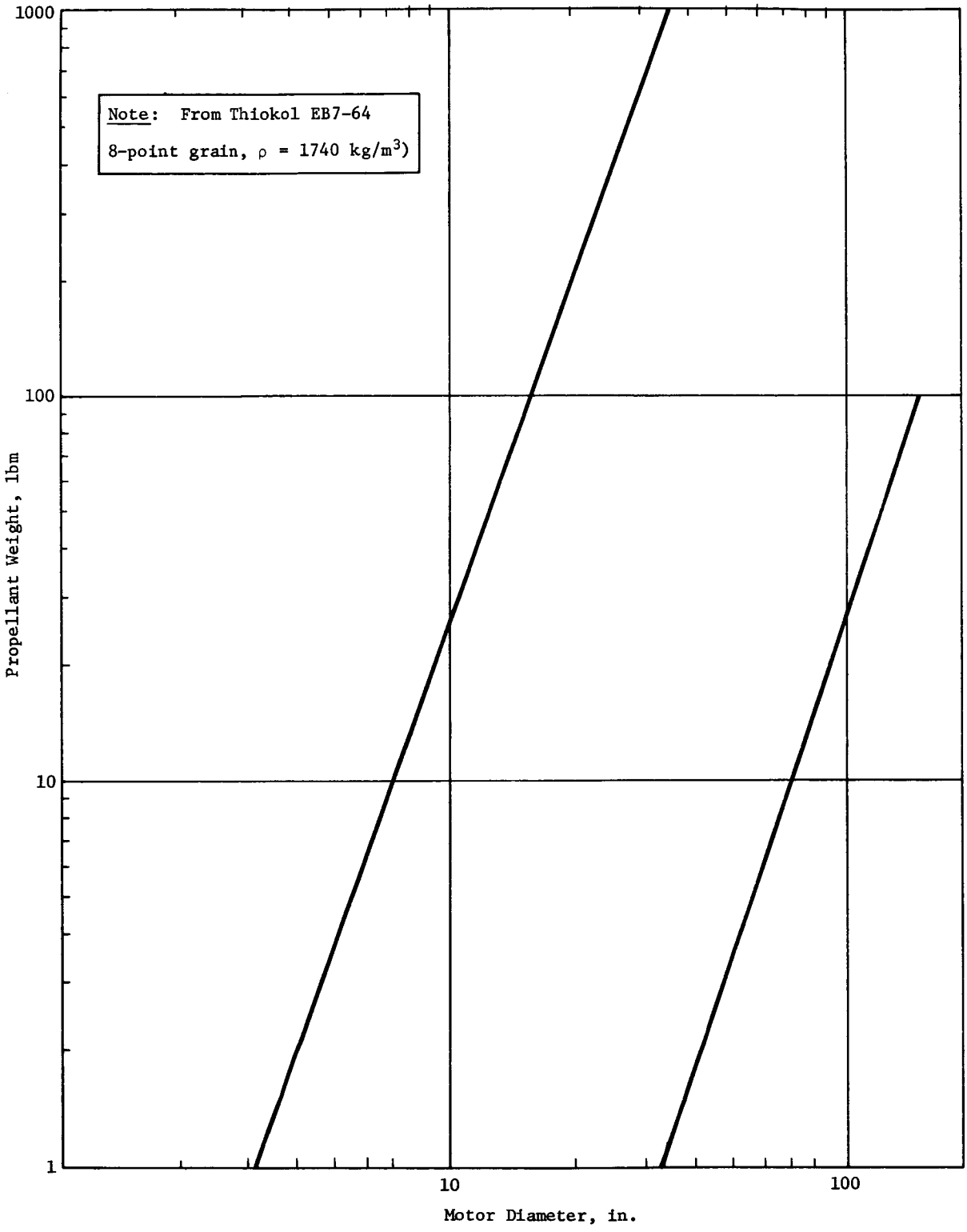


Figure M-4 Motor Diameter versus Propellant Weight

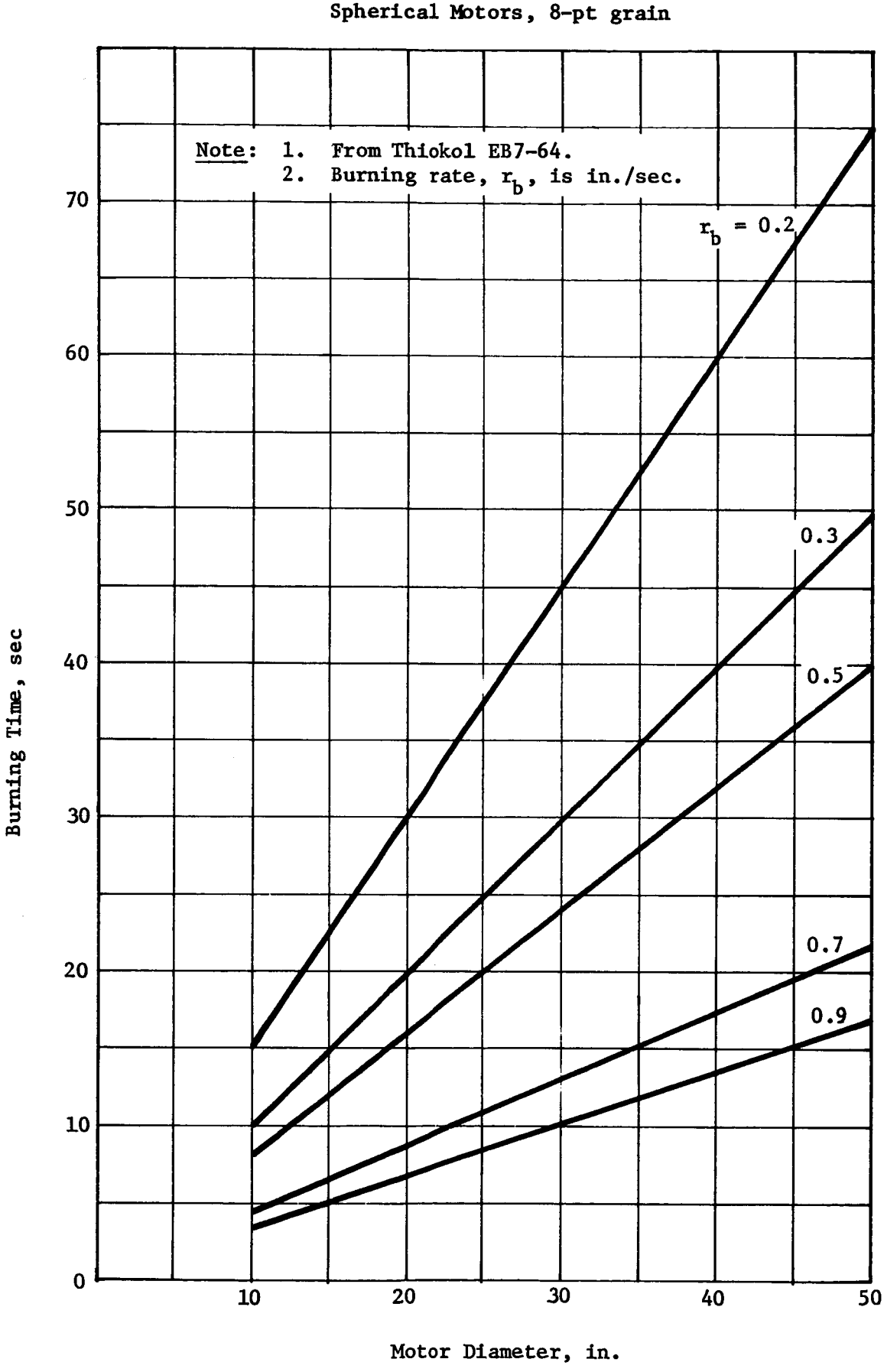


Figure M-5 Buring Time vs Motor Diameter

Although there is some choice in the combustion pressure that can be selected for the motor, the minimum motor weight generally is achieved at a pressure in the range of 3.45×10^6 to 4.13×10^6 N/m^2 (500 to 600 psia) where the chamber walls need not be excessively heavy, and the nozzle is still relatively small (and light). Assuming for convenience a chamber pressure of 3.8×10^6 N/m^2 (550 psia) and a nozzle area ratio of 40, a thrust coefficient of $\sim$ 1.78 may be predicted based on known nozzle performance. Then the required nozzle throat area is found to be $\sim$ 0.53 $in.^2$ or 0.265 $in.^2$ per nozzle. This yields a nozzle throat diameter of 1.47 cm (0.58 in.), an exit diameter of 9.3 cm (3.67 in.), and a divergent nozzle length of 14.4 cm (5.75 in.) assuming a nozzle half-angle of 15°. Then, assuming that the nozzle is $\sim$ 40% submerged in the spherical chamber, the protruding length will be 8.9 cm (3.5 in.). The foregoing outline configuration is shown in Figure M-6.

Based on previous experience with motors of similar size, and the performance achieved with the high energy propellants such as Thiokol TP-H-3062, there is every reason to believe that a suitable motor can be fabricated with loaded weight <34 lbm. Assuming that the mass fraction trend established by Thiokol motors TE-M-541 and -516 can be maintained with this new probe motor, a λ of 0.84 should be attainable. This would result in a motor loaded weight of 14.6 kg (32.3 lbm) (for a single nozzle configuration), or a weight of possibly 15.3 kg (33.8 lbm) to account for the additional nozzle.

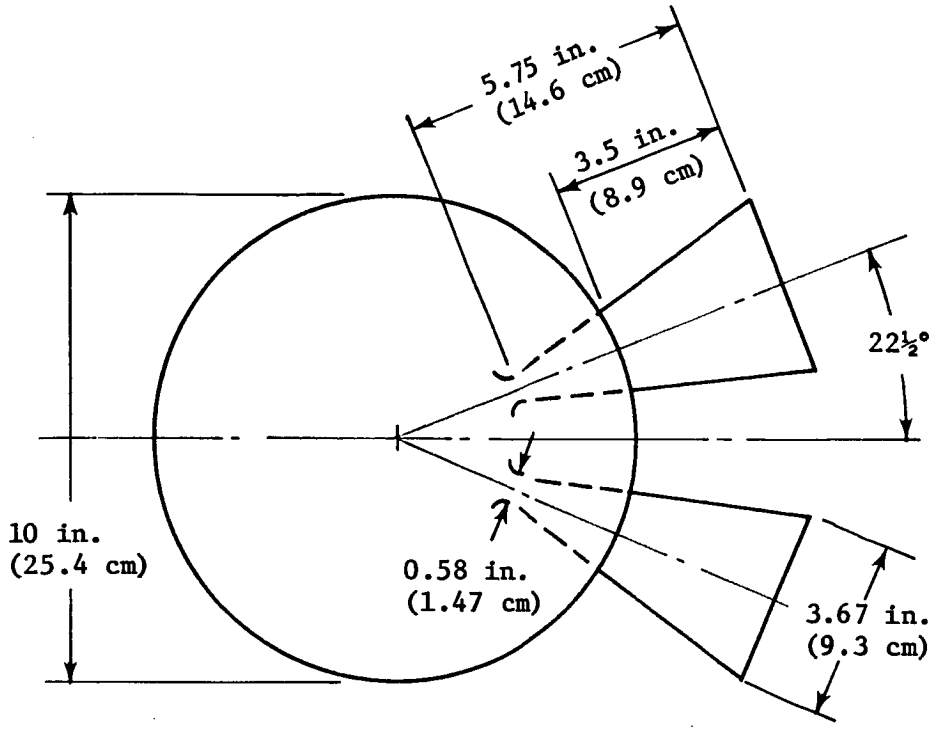


Figure M-6 Nominal Jupiter PRobe, Solid Motor Characteristics

Propellant Weight	12.3 kg (27.1 lbm)
Loaded Weight	15.3 kg (33.8 lbm)
Chamber Pressure, avg	3.7×10^6 N/m^2 (550 psi)
Burn Time	15 sec
Thrust, gross	2310 N (520 lbf)
Thrust, net	2135 N (480 lbf)
Total Impulse, gross	34,600 N sec (7770 lbf sec)
Total Impulse, net	31,900 N sec (7180 lbf sec)

B. AUXILIARY PROPULSION

The cold gas system has been evolved to accomplish the four auxiliary propulsion functions: spin, despin, precess for the probe, plus deflection of the service module. The system is depicted schematically in Figure M-7. It may be considered to consist of five subsystems, i.e., the four subsystems that accomplish spinup, precession, despin, and module ejection, respectively, plus the gas supply subsystem that provides GN_2 to the thrusters under the proper conditions. This system does not necessarily represent the optimum solution to the propulsion requirements, but it appears to be a good solution in that it has sufficient redundancy to assure a high reliability, yet is not unnecessarily complex and heavy. Redundancy is provided for all valve functions.

It is envisioned that the system will use GN_2 as the working fluid, stored at an initial pressure of $\sim 24.5 \times 10^6$ N/m^2 (3500 psi). Fluids other than GN_2 conceivably could be used, but they offer very little advantage in terms of performance and/or system weight. Storage at this pressure level is somewhat arbitrary, but results in a pressure vessel volume that is not too large, and provides a greater selection of system components. A conventional pressure regulator is used to reduce the pressure to $\sim 17 \times 10^4$ N/m^2 (25 psia) for use by the thrusters.

The majority of the thruster/valve clusters are located at the periphery of the probe to provide the maximum possible moment arm, and are interconnected to the GN_2 supply system by means of stainless steel tubing. To minimize system leakage, all joints are either welded or brazed. The selection of specific components for the system has not been pursued in depth, but potential suppliers and even candidate components have been identified to some degree. The next step in the evolution of the design would be to evolve a detailed system layout that defines each individual component, the interconnecting line sizes and configurations, and the mounting provisions.

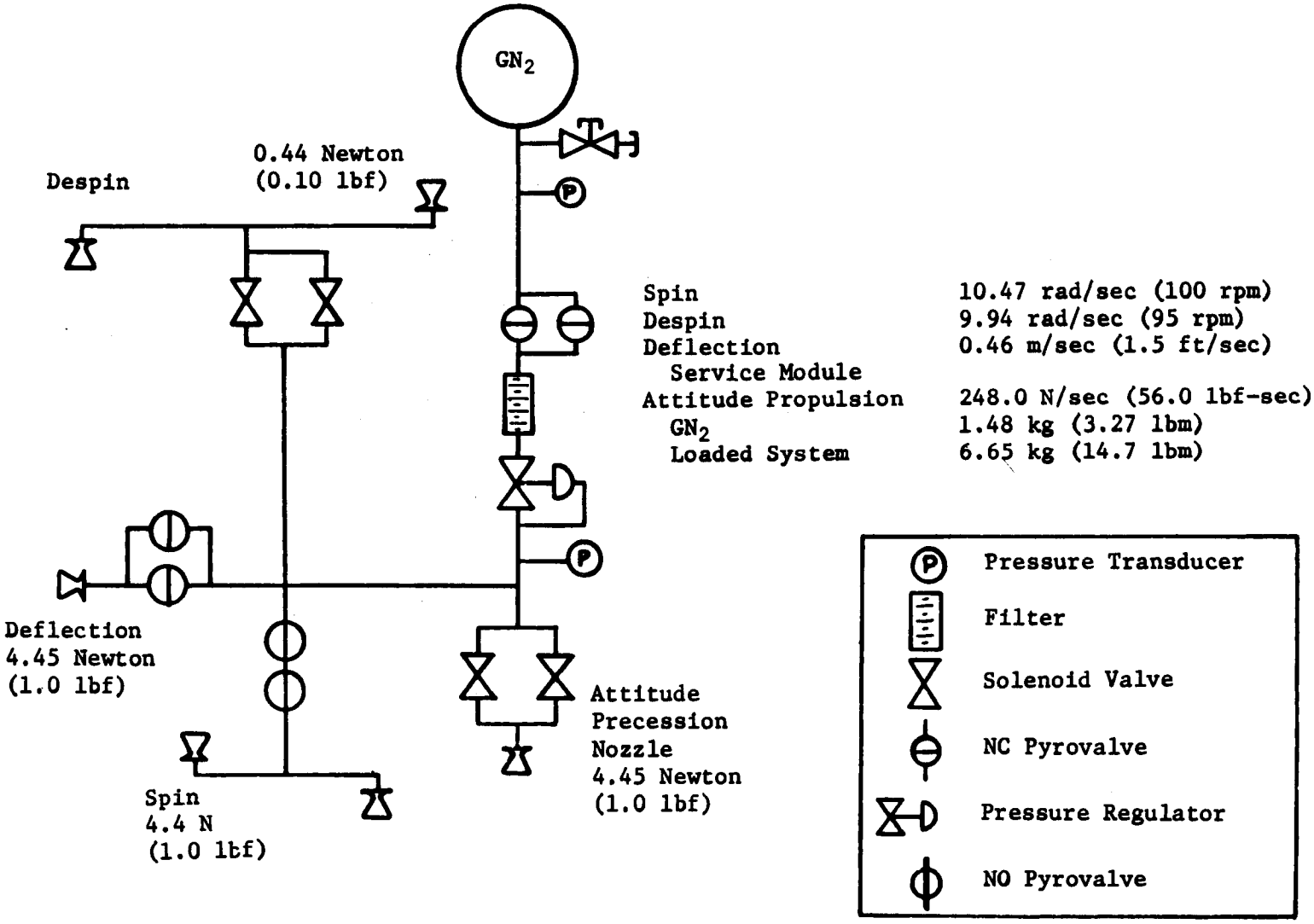


Figure M-7 Auxiliary Propulsion Schematic

1. Spinup Subsystem

The first subsystem to go into operation is the spinup system that accelerates the probe to a rotational velocity of $\sim$ 10.5 rad/sec (100 rpm) before the firing of the ΔV motor. As will be noted on the schematic, the system selected is extremely simple and at the same time highly reliable. The subsystem is not provided with an independent start capability. Instead, the pyro valves in the gas supply subsystem are fired to activate the thrusters, and to provide gas up to the control valves of the other auxiliary subsystems. Then after the required operating period, thrust is terminated by firing the series redundant N/O pyro valves. The elimination of valving to control each of the two thrusters individually will result in a longer thrust tail-off than otherwise, but the tailoff impulse is insignificant compared to the total spinup impulse.

The selection of the thrust level to be used is to some degree arbitrary, but not completely without guidelines. From purely propulsion considerations, a low thrust level is desired because it leads to valves, thrusters, and interconnecting lines that are small and lightweight. On the other hand, as the thrust level decreases and the spin time increases, the pointing accuracy of the probe is degraded rapidly. From a structural standpoint, high thrusts may not be desirable, but the shorter thrust periods are advantageous to the guidance system. The 4.4 N (1 lbf) thrust level appears to represent a reasonable compromise between two extremes, though no real attempt has been made to determine the optimum thrust, if indeed one can be defined. Thruster/valve clusters in the 4.4 N (1 lbs) thrust category are relatively common (and available) and are not excessively heavy, yet provide a spinup time interval that does not appear to be too long. To provide the required 276 N/sec (62.8 lbf sec) impulse with two 4.4 N (1 lbf) thrusters, it is evident that the burn time will be only slightly more than 30 sec.

During the continuous burn of this magnitude, (expelling $\sim$ 1/4 of the stored gas), performance $\left(I_{sp}\right)$ will decrease slightly as the gas temperature drops. This will result in the consumption of a larger quantity of gas than that previously computed for the spin-up maneuver, but the total delivered impulse can still be predicted very accurately. The added GN_2 required has been accounted for in the 30% "pad" provided in the storage gas requirements.

The calculations for the ACS system sizing is presented in this Appendix following the system description.

2. Despin Subsystem

The second auxiliary propulsion function to be performed is the precession of the probe axis to the proper Jupiter entry angle, but the despin maneuver will be discussed first because of its similarity to the spinup maneuver. The despin subsystem provides the same torque to the probe as the spinup subsystem, but it is applied in the opposite direction to reduce the angular velocity of the probe from 10.5 rad/sec (100 rpm) to 52 rad/sec (5 rpm) before atmospheric entry.

The thrusters used in the two subsystems would be of identical designs, but the valving is different becuase the despin subsystem must have provisions for both start and shutdown. This capability conceivably could be provided by a combination of N/O and N/C pyro valves, but solenoid valves have been tentatively selected because they provide greater operational flexibility. The solenoid valves permit the application of a series of impulses to achieve the proper rpm should this mode of operation be found necessary. A predetermined thrusting interval (achieved with a timer) may not exactly provide the desired final probe rpm so that one or more vernier impulses may be required.

The tentatively selected valve cluster includes only two solenoids in a parallel redundant configuration. Consideration has been given to the use of a quad redundant configuration, but this does not appear to be necessary. The two-valve configuration provides a very high reliability because of the very limited number of operational cycles involved (possibly, only one), the very low probability of failure to close once the valve has opened, and the negligible overall effect of leakage through the valve seat. All the auxiliary propulsion functions will have been accomplished within a few hours after the termination of the despin impulse, so the quantity of gas that could be lost as a result of "normal" valve leakage is insignificant.

Sizing of the despin thruster is not at all critical. Large thrusters would not be appropriate because they would be unnecessarily heavy, but small thrusters could be used without detrimental effects. Adequate time is available to accommodate a prolonged despin maneuver. To minimize the number of different sizes of components, however, 4.4 N (1 lbf) thrusters have been selected to provide the despin function. With thrusters of this

size, despin will be accomplished in slightly less time than spinup (within ∿ 30 seconds), consuming 0.376 kg (0.83 lbm) of GN_2 in deliveriging 267 Nsec (60 lbf sec) impulse.

3. Precession Subsystem

The precession subsystem applies a moment about one transverse axis of the probe to effect precession of the probe about a second axis at 90° to the first, eventually rotating the probe longitudinal axis through an angle of 0.89 rad (51°) for proper Jupiter entry attitude. This torquing of the probe is accomplished by pulsing the precession thruster for a short time, usually once each revolution. A single thruster has been selected to provide the required torquing. This results in the application of a small ΔV to the probe in addition to the moment, but this appears to present no particular problem. The use of a single thruster, of course, results in minimum system complexity and weight.

The one operating requirement that is different for this subsystem is the necessity for repeated pulsing of the thruster. Consequently, it is mandatory to use solenoid valves instead of pyro valves to control the thruster. The selection of parallel redundant valving rather than quad redundant valves follows the same basic logic as for the despin subsystem; i.e., a very high reliability is achieved without resorting to a four-valve configuration.

The choice of thrust level for the precession thruster is somewhat more critical than for other subsystems. Application of a high torque to the probe will produce a pronounced undesirable nutation, though the precession will be accomplished with a relaively small number of pulses and in a short elapsed time. Application of a low torque results in only a very small amount of nutation, but requires a relatively large number of pulses (resulting in lower reliability), and consumes an excessive amount of time. To provide the 249 Nsec (56 lbf sec) impulse required with a single 4.4 N (1 lbf) thruster, it is evident that 56 seconds of thruster operation is required. If each thruster pulse is restricted to 0.78 rad (45°) of probe rotation (1/8 revolution), it is evident that the elapsed time required to accomplish precession will be ∿ 7.5 minutes; the total number of pulses required is ∿ 750. The application of thrust must be limited to approximately 1/8 of the probe revolution in order to achieve maximum efficiency. As the angle of rotation during thrust application increases, the effective moment arm decreases, thereby necessitating a greater total impulse and increased consumption of GN_2. If a 0.44 N (0.1 lbf) thruster were used, the number of pulses would increase to 7500, and the elapsed time to 1.25 hr.

4. Deflection Subsystem

The final function to be performed by the auxiliary propulsion system is to eject the service module (including the auxiliary propulsion system) from the probe just before Jupiter entry. The subsystem is required to provide a minimum impulse to deflect the module a safe distance from the probe, but there is no practical maximum limit to the impulse that can be tolerated. Only a very small total impulse is required, so the gas consumption is also small.

As seen from the system schematic diagram, it is proposed to provide a start capability, but no shutdown capability for the system. Any excess gas remaining in the system will simply be allowed to blowdown through the thruster, thereby providing a ΔV to the service module in excess of the minimum requirement. The simplest most reliable valving for this function appears to be the parallel redundant N/C pyro valves shown. These valves provide a reliability of nearly 1.0 for initiating the thrust; they are not required to provide thrust termination.

The thrust level to be provided for this function is not at all critical. The selection of the 4.4 N (1 lbf) thruster was made simply to achieve uniformity of components, but other thrust levels would accomplish the deflection maneuver equally well. The 4.4 N (1 lbf) thruster will accelerate the 25 kg (55 lbm) service module at a rate <0.02 g, and achieve the desired minimum service module ΔV of 1.5 fps in less than 3 sec, consuming less than 0.02 kg (0.04 lbm GN_2).

5. Gas Supply Subsystem

This subsystem must provide long-term storage for all of the gas to be used for the auxiliary propulsion functions, and subsequently supply the gas to the thrusters under the required conditions of pressure, flowrate and cleanliness. It is envisioned that the subsystem will consist of a pressure vessel for storage of the compressed gas, a fill valve for loading the gas into the system, pyro valves to isolate the gas from the thrusters until needed, a pressure regulator to reduce the pressure from the maximum storage value of 24.6 N/m^2 (3500 psi) to a usable constant level of 17×10^4 N/m^2 (25 psia), a filter to remove particulate contaminants, and transducers to monitor storage and regulated pressures. Since the thruster subsystems do not operate simultaneously, the gas supply components need to be sized to accommodate a maximum flowrate corresponding to the operation of only two 4.4 N (1 lbf) thrusters.

The total amount of gas required by the thrusters is ∿ 1.13 kg (2.5 lbm). Since the stored gas is effectively isolated from the thrusters throughout a majority of the mission, leakage can be held to a negligible amount by careful quality control of the welded and brazed joints. Since the thrusters are activated for only the final few days of the mission, they should not contribute a significant amount of leakage even if the valve seats should become contaminated with particulate matter. However, a quantity of gas somewhat greater than 11.3 kg (2.5 lbm) is required to account for some inefficiencies in the thruster outputs, and provide a reasonable safety factor. Normally, it would also be necessary to account for a significant amount of residual unusable gas at the end of the mission, but, in this case, the system will be blown down during the final deflection maneuver so that all the remaining gas is effectively used.

It was noted previously that thruster performance during the long spinup and despin maneuvers will probably fall a few percent below the assumed I_{sp} of 705 Nsec/kg (72 sec). In view of this, it is proposed to provide an initial charge of gas that is 30% greater than the summation of the thruster requirements; i.e., 1.48 kg (3.27 lbm) instead of 1.13 kg (2.5 lbm). It is believed that this will provide an adequate factor of safety for this specific type of mission.

It is proposed to use parallel redundant N/C pyro valves to provide isolation of the stored gas until needed by the thrusters. These valves are very simple, light in weight, and highly reliable. They do not leak before activation, and they exhibit an extremely low failure rate (reliability nearly 1.0).

The presence of the pressure regulator results in a somewhat low reliability for the subsystem, but this is unavoidable. The regulator is absolutely essential to the proper operation of the system. Unfortunately, however, about the best reliability that can be expected is 0.9975, which leads to a subsystem reliability of approximately the same value.

6. Component Selection

It is not intended as part of the current study to make final selections of the components to be used in the auxiliary propulsion system. Final selections would only be made after a more detailed analysis of system requirements had been completed, and an in-depth search for state-of-the-art components had been conducted. However, the current study has proceeded to the point of identifying

Table M-1 Pressure Vessels

MANUFACTURER	VOL $in.^3$	PRESSURE, psi	$PV(10)^{-6}$	SIZE OF SPHERE, in.	MATERIAL	WEIGHT, lbm	PART NO.	REMARKS
Menasco	68	4,500	0.306	5.29	6Aℓ-4V	1.8	823000-505	
Menasco	75			5.48	6Aℓ-4V	2.7	782000-503	
Menasco	75	3,000	0.225	5.36	4340	2.1	848000-501	
Tavco	75	3,000	0.225	5.29		1.75	23711407	Emergency brakes for B-58
Tavco	75	3,000	0.225	5.29	4130	2.0	23711546	GN_2 tank for Agena
Menasco	83	3,000	0.249	5.62	6Aℓ-4V	1.6	730500-501	
Airite	83	3,600	0.299	5.65	6Aℓ-4V		6428	Tank for JPL
PSI	85	6,000	0.510	5.9	6Aℓ-4V	2.57	80075-1	Tank for Mariner Mars
PSI	87.5	6,000	0.525	5.9	Inc 718	3.94	80101-1	GH_2 tank for Mariner Mars
Brunswick	100	3,000	0.300	6.5	Glass/ Epoxy	2.8	3002	GN_2 tank for F-106
Fansteel	100	1,600	0.160	5.75	6Aℓ-4V	1.65	4425002	He tank for Saturn
Tavco	100	3,500	0.350	5.95		2.4	23711400	Air/GN_2 for B-58
Whittaker	100	3,250	0.325	6.17	Glass/ Epoxy	2.4	ASFW100	For aircraft
Fansteel	103	3,250	0.335	5.95	6Aℓ-4V	1.0	4425033	
Fansteel	113	4,000	0.452	6.0	6Aℓ-4V	1.3	107519	Gas for Vela Hotel
PSI	113	10,000	1.13	6.0	6Aℓ-4V	1.67	80094-1	GN_2 for Mariner Mars Application
Menasco	130	3,670	0.477	6.5	6Aℓ-4V	2.1	806000	
Menasco	157	3,000	0.470	7.31	6Aℓ-4V	3.0	864000-503	
Menasco		3,000		6.34	6Aℓ-4V	3.0		GN_2 for ACS on OSO
Fansteel	160	6,750	1.08	7.024	Inc 718	7.2	4425038	O_2 Tank for IOPS

at least the major functional requirements (specifications) for each component, the potential vendors, and in some cases, a specific candidate that appears to be a reasonably good selection. The results of this selection are given in the body of the report.

Since the pressure vessel is by far the largest and heaviest component in the system, it was studied in somewhat greater detail than the others. It sized as follows:

To contain 1.48 kg (3.27 lbm) of gas, the vessel must have a pressure-volume product of at least

$PV = wRT = 3.27\ (55.1)\ (530) - 95{,}500$ psf $ft^3 = 1.145 \times 10^6$ psi $in.^3$.

Since in this application it is proposed to use three pressure vessels to distribute the weight uniformly about the probe axis,

$PV = 0.382(10)^6$ psi $in.^3$ per vessel.

Then, referring to Table M-1, a tabulation of existing pressure vessels, it will be seen that a reasonable selection is a 15.2 cm (6 in.) diameter titanium alloy vessel manufactured by Fansteel for gas storage on the Vela Hotel Satellite. This vessel ($PV = 0.452(10)^6$ is somewhat larger than actually required, but is probably a good selection because it does provide a comfortable margin of safety. To contain the required amount of GN_2, it would have to be charged to only $\sim 23.4 \times 10^6$ N/m^2 (3400 psi) instead of the design value of 27.6×10^6 N/m^2 (4000 psi). It weighs only 0.58 kg (1.3 lbm), so three of them will weigh less 1.8 kg (4 lbm). This is a storage vessel only 22% greater than the weight of the contained gas, indicating a very good design.

7. Auxiliary Propulsion Impulse & Calculations

SPINUP:

$I_z = 9.0$ slug ft^2
final angular velocity - 100 rpm
thruster lever arm - 1.5 ft
$I_{sp} = 72$ lbf sec/lbm

$$Ft = \frac{I_z \Delta\omega}{2L} \text{ lbf sec/thruster}$$

$$\Delta\omega = \frac{100}{60} 2\pi = 10.47 \text{ rad/sec}$$

$$Ft = \frac{9(10.47)}{2(1.5)} = 31.4 \text{ lbf sec/thruster}$$

$$= 62.8 \text{ lbf sec for 2 thrusters}$$

DESPIN:

Assume final angular velocity - 5 rpm

$\Delta\omega = 0.95(10.47)$ rad/sec

Ft - 0.95(62.8) - 59.6 lbf sec

PRECESSION:

Assume precession angle - 51° (at 100 rpm)

$$W_P = \frac{I_z \omega}{I_{sp} L} \frac{2\pi\theta}{360} = \frac{9(10.47)\ 2\pi\ (51)}{72(1.5)\ (360)}$$

$$= 0.776 \text{ lbm } GN_2 \text{ required}$$

Ft = 0.776(72) - 55.8 lbf sec

DEFLECTION:

Assume service module mass - 55.8 lbm

service module ΔV = 1.5 fps

$$Ft - \frac{W\Delta V}{g} = \frac{55.6(1.5)}{32.2} = 2.6 \text{ lbf sec}$$

TOTAL IMPULSE:

Ft = 62.8 + 59.6 + 55.8 + 2.6 = 180.8 lbf sec

GN_2 Required - $\frac{180.8}{72}$ = 2.52 lbm

W_p (total) including leakage allowance - 2.52(1.3) = 3.27 lbm

Assume storage bottle weight - 3.27 (1.3) - 4.25 lbm

		kg	lbm
Component weights:	Fill Valves (1)	0.11	0.25
	Transducers (2)	0.23	0.50
	Squib Valves (6)	0.68	1.50
	Filters (1)	0.16	0.35
	Regulators (1)	0.18	0.40
	Solenoid Valves (8)	0.72	1.60
	Thrusters, 1 lbf (6)	0.54	1.2
	Lines	0.72	1.6
	Component Total	33.4	7.4

Loaded System Weight = 3.27 + 4.26 + 7.4 = 14.93 lbm

C. RELIABILITY COMPARISONS

1. General

Solid propellant motors inherently possess a high reliability because of their extreme simplicity, and their relatively advanced state of the art. Estimates of reliability for new designs are usually based on the demonstrated reliability of prior designs for which the motor components, materials of construction, and service applications are essentially the same as those for the

proposed design. The observed component failure rates are combined by rss addition to provide a quantitative estimate of failure probability (and reliability). Typical of the reliability estimates made by solid motor fabricators is that provided to Martin Marietta by Aerojet. Based on various component tests ranging in number from 122 to 2878, and a total number of failures of only 5, a best estimate of motor reliability for this particular application is 0.997. To actually attain this level of reliability, however, the proposed design must be subjected to a carefully planned development and qualification program.

Liquid (and gaseous) propellant systems tend to be less reliable than solid propellant motors because of their greater complexity, but this deficiency can usually be compensated for by providing redundancy for the critical system components (principally, valves). Using conventional reliability theory, a reasonably accurate quantitative estimate of system reliability may be made from the vast quantity of available statistical data of individual component failure rates, once the total system is adequately defined.

For the particular case of the proposed monopropellant hydrazine system, a preliminary system schematic (Fig. M-8) was first developed, combining the requirements of the ΔV propulsion and the auxiliary propulsion into a single system. To achieve a high reliability, the system operates in a blowdown mode (no pressure regulator), and redundancy is provided for all valve operations. Then the reliability computations were made as presented herein. It will be noted that the ΔV thruster/valve reliability is estimated to be $\sim$0.9997, which combined with a tank/feed system reliability of essentially 1.0, still provides a reliability >0.999 for the ΔV portion of the system. The addition of the auxiliary propulsion thrusters and valving to the system reduces the overall system reliability (including the ΔV thruster) to a value slightly less than 0.996.

The cold gas system proposed for the auxiliary propulsion functions was treated in a similar manner to the hydrazine system. A complete system to accomplish the four auxiliary propulsion functions was first evolved, and is shown schematically in Figure M-9. Then the predicted reliability for the system was computed as shown in Section C2 of the Appendix. It will be noted that the reliability of the individual thruster/valve assemblies is very high (generally >0.9999), but the regulator reliability is estimated to be only $\sim$0.9975, thereby reducing the overall system reliability to $\sim$0.997.

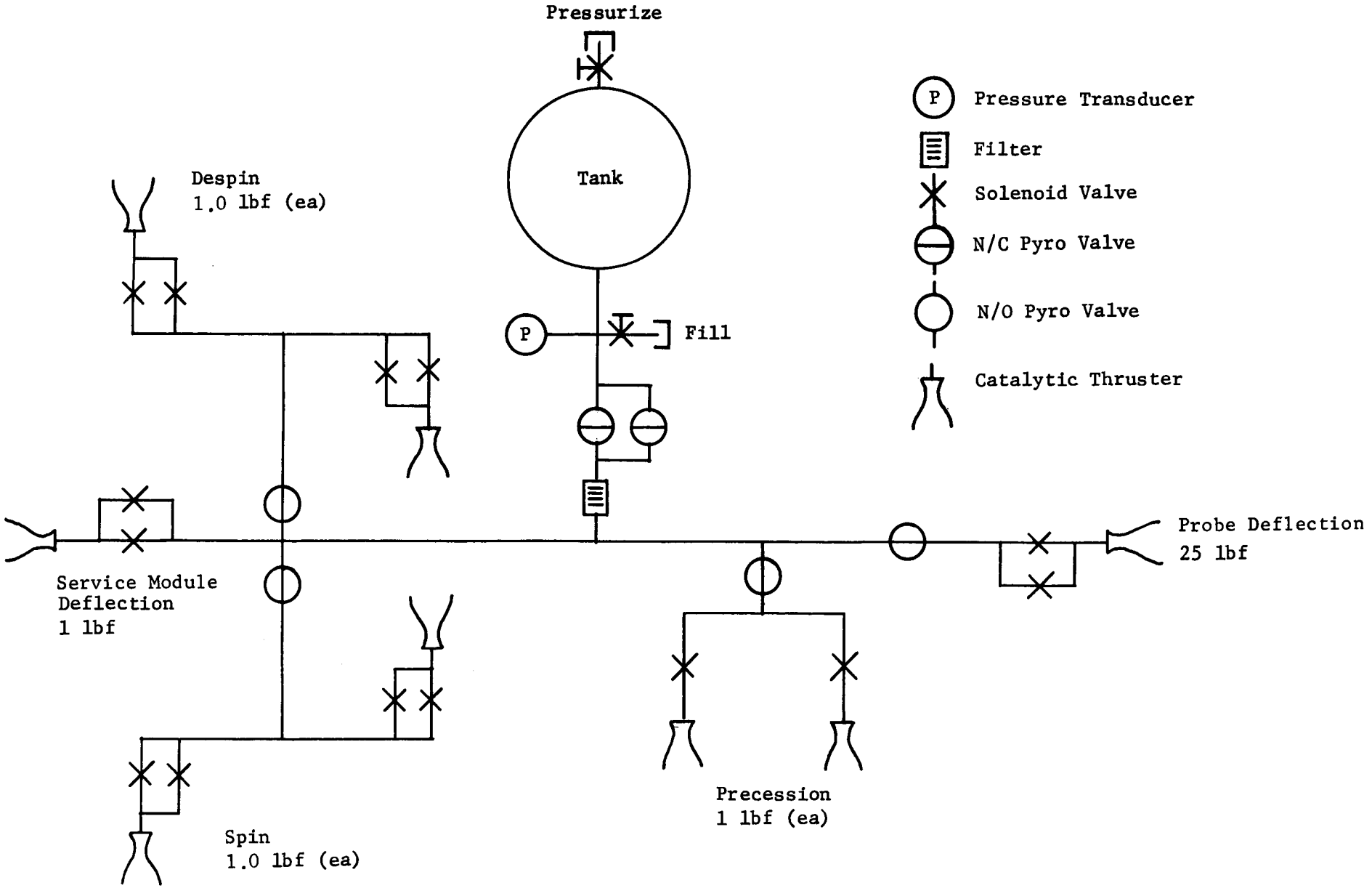


Figure M-8 Reliability Analysis System Schematic Monopropellant Hydrazine System

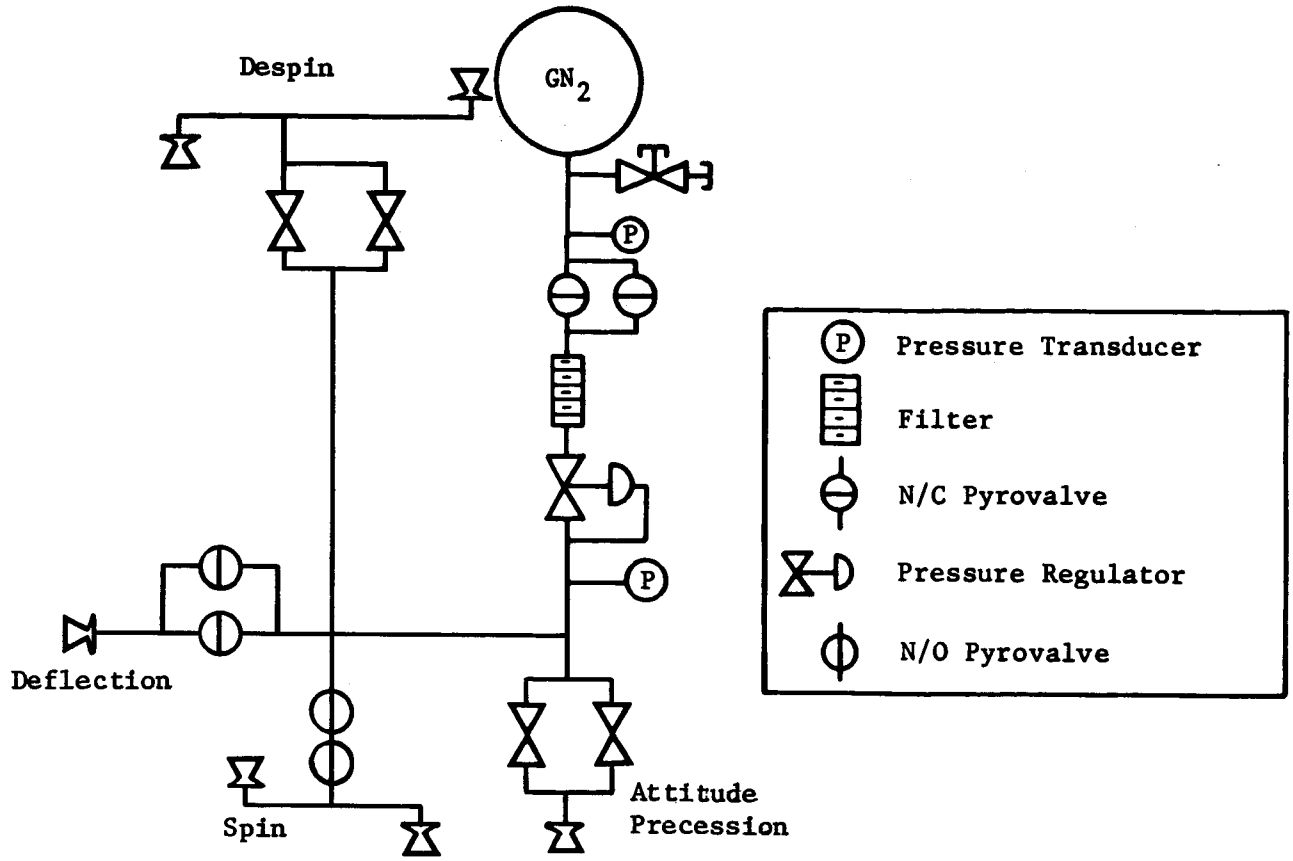


Figure M-9 Reliability Analysis System Schematic Cold Gas Attitude Control System

For a combined system of a solid motor (to provide the ΔV requirement) and the cold gas system (to provide the auxiliary propulsion requirements), the predicted reliability is only slightly greater than 0.994, compared to a predicted reliability for the integrated hydrazine system of nearly 0.996. It is evident that the hydrazine system appears to have a slight advantage with regard to reliability, but the difference is not particularly significant. The principal reason for this difference is the need for a pressure regulator in the cold gas system, whereas the hydrazine system operates in a blowdown mode.

2. GN_2 Subsystem Reliability Analysis

JPL DATA:

Single Valve and Thruster Reliability for 1000 cycles is 0.9622

Q per cycle for valve and thruster - $0.378\ (10)^{-4}$

Average Q per valve - $1\ (10)^{-6}$/cycle

Q per thruster - $36\ (10)^{-6}$/cycle

ATTITUDE PROPULSION:

One thruster, two valves in parallel, 1000 cycles of operation

$R = [1 - (1000(10)^{-6})^2] [1 - 1000(36)(10)^{-6}]$

$= (0.999999) (0.999964) - 0.99996$

SPIN:

Two thrusters, two NO squib valves in series, one cycle of operation

Q for squibs - 0.0003/operation

$R = [1 - 36(10)^{-6}]^2 [1 - 0.0003^2]$

$= (0.99993) (0.99999^{+}) = 0.9999$

DESPIN:

Two thrusters, two valves in parallel, one cycle of operation

$R = [1 - 36(10)^{-6}]^2 [1 - (10^{-6})^2]$

DEFLECTION:

One thruster, redundant pyro valves, one operation, Rx 1.0

SUPPLY SUBSYSTEM:

2 squib valves N/C in parallel

Q/valve - 0.003

$R = 1 - 0.003^2 = 1 - 9 (10)^{-8} \approx 1.0$

FILTER:

$R \approx 1.0$

REGULATOR:

$Q = 2.5 (10)^{-6}$/cycle

1000 cycles estimated

$R = 1 - 10^3 (2.5)(10)^{-6}$

$= 0.9975$

R_{TOTAL} SUBSYSTEM

= (0.9999) (0.9999) (0.9975)

= 0.99736

3. Monopropellant Hydrazine System Reliability Analysis

Valve (single) and thruster reliability = 0.9479/1000 cycles

Q per cycle - $\frac{(1-0.9479)}{1000}$ = $52(10)^{-6}$ for valve and thruster

Q for valves: Marquardt, Q = $0.1(10)^{-6}$/cycle

RADC, Q = $1.6(10)^{-6}$/cycle

TRW, Q = $0.3(10)^{-6}$/cycle

Use Q = $1(1)^{-6}$ as conservative estimate

Q for thrusters = $51(10)^{-6}$/cycle

ΔV THRUSTER:

One thruster with parallel valves and a N/O squib shut off
Operation: <5 cycles

Valves are redundant to "final to open" (parallel) and redundant to "fail to close" (N/O squib valve).

$R = [1 - 5(51)(10)^{-6}] [\{1 - 5(10)^{-6}\}^2]$

= 0.99975 for open and operate mode

Use of N/O squib valve results in R ≈ 1.0 for fail to close mode

PRECESSION:

Two thrusters, each with single valves and a N/O squib valve. Operation 1000 cycles. Thrusters are redundant in that either can perform the function

R (per leg) = $[1 - (1000)(10)^{-6}] [1 - 1000(51)(10)^{-6}]$

= (0.999)(0.949) - 0.948 Q - 0.052

For redundant thruster operation:

$R_{Total} = (1 - 0.052^2) = 0.9973$

SPIN:

Two thrusters, each with parallel valves and a N/O squib valve

Operation: 1 cycle

$R = [(1 - (10)^{-12}) (1 - 51 (10)^{-6})]^2$

$= (0.99995)^2 = 0.9999$

DESPIN:

Same configuration as spin, but 5 cycles

$R = [1 - 255 (10)^{-6}]^2$

$= 0.9995$

DEFLECTION:

One thruster, parallel valves. Valves must open once.

$R = (1 - 10^{-12}) (1 - 52 (10)^{-6})$

$= 0.9995$

SUPPLY SYSTEM:

Parallel N/C squib valves

Q/valve - 0.0003

$R_{Total} = 1 - 0.0003^2 = 1 - 9 (10)^{-8} \approx 1.0$

Filter: $R \approx 1.0$

TOTAL SUBSYSTEM:

$R = (0.99975) (0.9973) (0.9999) (0.9995) (0.9995)$

$= 0.9959$

D. PLUME CONTAMINATION

Although a rigorous analysis of the solid motor plume is beyond the scope of this study, a cursory analysis was performed to identify the magnitude of the problem, and provide confidence that the selected solution (canted nozzles) is valid. To minimize the effects of the exhaust plume on the mother spacecraft, it is planned that the probe will have separated at least 315 m (1000 ft) from the mother spacecraft before the probe solid motor is fired, but even at this distance, the impingement problem can not be ignored. If the exhaust products were entirely gaseous, they probably could be tolerated, but unfortunately, they contain a large solid content. The 16% Aℓ contained in the propellant oxidizes to form $A\ell_2O_3$ solid particles that comprise ∿34% of the exhaust products by weight. These particles are of sufficient size and are traveling at sufficiently high velocities that they constitute, in effect, a small belt of low velocity micrometeoroids. Their impact on science instruments (lenses, in particular), thermal control coatings, and thin insulation blankets can produce very detrimental effects that must be avoided if at all possible. Since the aluminum is essential in the propellant for attainment of high performance (specific impulse), it can not easily be eliminated, but impact on the spacecraft can be prevented to a degree by proper aiming of the exhaust flow. The approach to evaluating the problem follows.

1) To estimate the magnitude of the plume impingement problem for solid propellant motors containing significant percentages of aluminum, it is necessary to know the approximate sizes of the solid particles in the exhaust, as well as the flow direction and velocity.

    a) Regarding particle size, Reference 1 states "no theories capable of providing a particle size distribution have appeared." However, direct measurements reported in Reference 2 indicate that the solid (predominantly $A\ell_2O_3$) particles are essentially spherical in shape, and have "a mass average diameter between 2 and 3 μ." Further, it was observed that "the particle size seems to be insensitive to engine size, configuration, propellant ingredients, input aluminum particle size, and chamber pressure."

b) A comprehensive analytical study of solid particle flow paths reported in Reference 3 concludes that "only the smallest particles follow the gas and that the largest particles are concentrated near the axis, filling only about a third of the nozzle area at the exit plane." "Thus the particle flow field in any nozzle exit cone is essentially conical and the particles' drag on the gas will force the gas flow field to be essentially conical also." Figure M-10 shows quantitative results of the analyses for a nozzle with a divergent 15° half angle. The streamlines shown represent the outer boundaries for particles of the size indicated. Thus it will be seen that the heavy (5 to 10 μ diameter) particles appear to continue indefinitely on straight streamlines within the boundary of the extended nozzle exit cone. The lighter particles, however, follow slightly curved paths that extend outside the once. The number of particles traveling outside the 15° half-angle cone is relatively small, but it definitely is not zero.

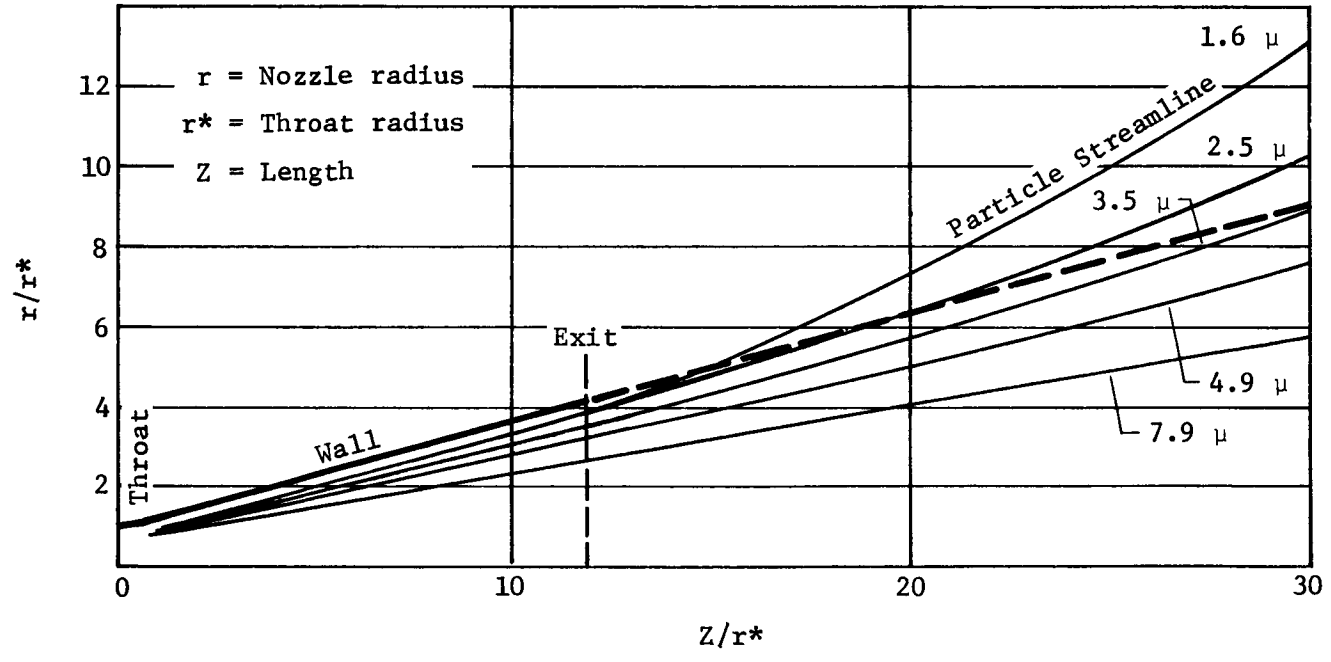


Figure M-10 Solid Particle Streamlines

c) The velocity of the particles issuing from the nozzle will be of the same order of magnitude as the effective exhaust velocity $\left(V_e \approx 9000 \text{ fps for a high performance solid propellant motor}\right)$. Reference 1 notes that "particles of less than 2 μ diameter will follow the gas velocity and temperature quite closely, whereas larger particles exhibit sizeable lags."

2) Using the above data, a rough order of magnitude estimate of the impingement effects on a mother spacecraft may be as follows:

a) Assuming an average particle size of 2 μ diameter, and a spherical shape, the mass of the average particle is

$$m = \frac{\pi}{6} \left(\frac{0.002}{25.4}\right)^3 \frac{248}{1728} = 3.7(10)^{-14} \text{ lbm/particle}$$

b) Assuming the solid propellant motor contains 27 lbm propellant to be consumed in ∿15 sec, the rate of generation of exhaust products is

$$\frac{27}{15} = 1.8 \text{ lbm/sec}$$

c) Using the following theoretical exhaust composition for the TP-H-3062 propellant (Reference 4).

Constituent	mol/100 gm	M	% by wt
$HC\ell$	0.5674	36	20.40
N_2	0.2944	28	8.25
H_2O	0.2435	18	4.38
H_2	1.4583	2	2.92
CO	1.0023	28	28.04
CO_2	0.0351	44	1.54
$A\ell_2O_3$	0.3334	102	34.00
Other			.47
			100.00

it is evident that the $A\ell_2O_3$ particles will be generated at a rate of

$0.34(1.8) = 0.61$ lbm/sec, or

$$\frac{0.61}{3.7(10)^{-14}} = 1.65(16)^{13} \text{ particles/sec}$$

d) Assuming a nozzle divergence half angle of 15° and a separation distance of 1000 ft between the nozzle (probe) and target (spacecraft), the cross-sectional area of the extended cone is found to be

$$A = \frac{\pi}{4}\left[2(1000) \tan 15^{\circ}\right]^2 = 225{,}000 \text{ ft}^2$$

e) Assuming the flow to be uniform across the cross section of the cone (This is only a very rough approximation.), the rate of impact on the spacecraft is found to be

$$\frac{1.65(10)^{13}}{225{,}000} = 7.4(10)^7 \text{ particles/ft}^2\text{/sec}$$

$$= 5.1(10)^5 \text{ particles/in.}^2\text{/sec}$$

The rate of impact will decrease markedly during the 15-sec burn time of the motor, but the total number of impacts probably would still be $>(10)^6$ particles/in.^{2}

The particles probably do not have sufficient momentum to penetrate multilayer insulation blankets, but they undoubtedly would degrade the performance of an insulation blanket, in addition to contaminating instrument lenses and thermal control coatings.

3) The use of canted nozzles obviously will alleviate the problem, but not eliminate it entirely. With canted nozzles it would be expected that none of the heavier (>5 μ diameter) particles would impact the spacecraft. Likewise, the vast majority of the lighter particles would be directed away from the spacecraft, but a few of the smaller particles would travel on a collision course. The question remains whether the number of impacts of these particles is sufficient to be of any real concern. It has been tentatively concluded that the impacts do not present a significant problem, but this is worthy of further investigation.

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   a) Development of an Adhesively Bonded Beryllium Propulsion Structure for the Mariner Mars 1971 Spacecraft, JPL, TM 33-517, January 1972.

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APPENDIX N

RESPONSE TIME FOR A BALLAST VOLUME TYPE MASS SPECTROMETER INLET SYSTEM

W. Fraser

March 7, 1972

P72-44487-097

M-E-M-O-R-A-N-D-U-M

TO: S. L. Russak, K. Ledbetter, L. Bergquist

FROM: W. Fraser

DATE: 07 March 1972

SUBJECT: Response Time For A Ballast Volume Type Mass Spectrometer Inlet System

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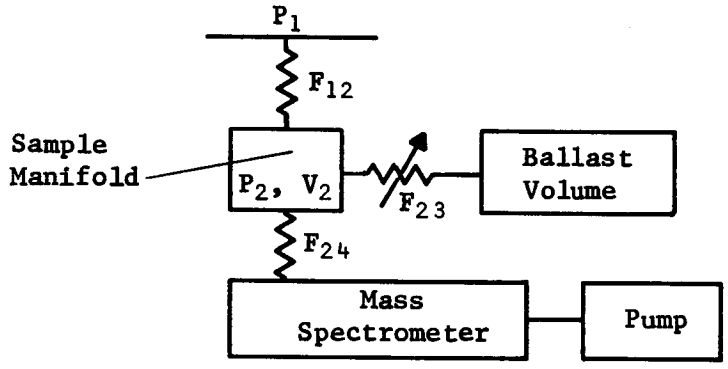
A previous memorandum* has discussed an inlet system for a mass spectrometer which decends slowly through the atmosphere of a planet, such as Venus or Jupiter, which has a dense atmosphere. The system is shown schematically in the figure below:



F_{12} System Inlet Leak

F_{23} Ballast Inlet Leak

F_{24} Mass Spectrometer Inlet Leak

Mass Spectrometer Inlet System

The system functions by maintaining a constant pressure in the manifold. This is accomplished with a variable, servo controlled, inlet leak to the ballast volume. With inlet system volumes of the order of a liter and descent times of a few thousand seconds, such a system can be operated so as to present a constant pressure of a few torr to the mass spectrometer inlet leak.

A concern with an inlet system for a mass spectrometer on a planetary descent probe is its response time. This response time is determined by the leak conductances and system volumes and, for some gases, by reactions between the sample and the inlet system surfaces. The subject of this memorandum is the calculation of the system response time for gas, inlet surface combinations for which surface reactions contribute negligibly. This then represents, for a given set of system parameters, a calculation of a lower bound on the response time.

*P71-44487-281, L. Bergquist and W. Fraser: *Venus Mass Spectrometer Inlet System, Preliminary Analysis and Proposed Laboratory Investigation.*

The configuration analyzed here is subject to the following assumptions:

1. The system has been open long enough that the servo controlled ballast inlet is maintaining the manifold pressure at a constant level.

2. The pressure in the ballast volume is much lower than the manifold pressure. This occurs at high altitude where the response time is longest.

3. Gas flow through the mass spectrometer can be neglected relative to that into the ballast volume.

4. An incremental partial pressure step occurs for one atmospheric constituent.

The partial pressures $P^{(2)}$ and $P^{(1)}$ of the incremented gas and the rest of the gas in the manifold can be described in terms of the flow conductances and volumes of the above figure by the following equations:

$$V_2 \frac{dP^{(2)}}{dt} = (P_1^{(2)} - P^{(2)}) F_{12} - P^{(2)} F_{23}$$

$$V_2 \frac{dP^{(1)}}{dt} = (P_1^{(1)} - P^{(1)}) F_{12} - P^{(1)} F_{23}$$

$$P^{(1)} + P^{(2)} = P_0 \text{ (A Constant)}$$

Here, $P_1^{(1)}$ and $P_1^{(2)}$ are the partial pressures in the external atmosphere. We now wish to add an increment, ε, to the external partial pressure, $P_1^{(2)}$, and calculate the resulting manifold pressure, $P^{(2)}$, as a function of time thereafter.

$$P_1^{(2)} = \begin{cases} P_{10}^{(2)}, & t < 0 \\ P_{10}^{(2)} + \varepsilon, & t \geq 0 \end{cases}$$

$$P_1^{(1)} = P_{10}^{(1)}$$

$P_{10}^{(1)}$ and $P_{10}^{(2)}$ are the partial pressures in the atmosphere prior to adding the increment.

The resulting variations, $\delta P^{(1)}$ and $\delta P^{(2)}$, from initial partial pressures, $P^{(1)}$ and $P^{(2)}$, in the manifold as described by:

$$V_2 \frac{d(\delta P^{(2)})}{dt} = F_{12} \frac{P_0^{(1)}}{P_0} \varepsilon - (F_{12} + F_{230}) \delta P^{(2)}$$

$$\delta P^{(2)} + \delta P^{(1)} = 0$$

where $P_0^{(1)}$ is the intial partial pressure in the manifold of gas other than the incremented gas

and F_{230} is the initial value of the flow conductance into the ballast volume.

The differential equation for $\delta P^{(2)}$ has the following solution:

$$\delta P^{(2)} = \varepsilon (1 - f_0^{(2)}) \frac{P_0}{P_1} (1 - e^{-t/T})$$

where ε is the increment in the atmospheric partial pressure of the test gas

$f_0^{(2)}$ is the fractional abundance of the test gas prior to the step increase

P_0 is the manifold pressure

P_1 is the atmospheric pressure

and T is the response time constant given by: $T = \frac{P_0}{P_1} \frac{V_2}{F_{12}}$

Thus a step, ε, in the atmospheric partial pressure results in a step, $\varepsilon \left(1 - f_0^{(2)}\right) P_0 / P_1$, in the manifold, or sample, pressure with a rise time of $P_0 V_2 / P_1 F_{12}$.

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Experiment Engineering
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APPENDIX O

AEROSHELL STRUCTURE PARAMETRIC WEIGHT STUDY

T. B. Sharp

June 16, 1972

AEROSHELL STRUCTURE PARAMETRIC WEIGHT STUDY

I. INTRODUCTION

A parametric structural weight study was performed to evaluate the weight of the aeroshell structure as a function of pressure, base diameter, structural material, and shell construction. Four aeroshell diameters, two methods of construction, and two materials were considered in this study. The range of aeroshell diameters and design pressures was selected to encompass the various mission constraints for a Jupiter probe as well as probes to Saturn, Uranus, and Neptune.

II. METHOD OF AEROSHELL ANALYSIS

Conical Shell - Two types of construction (sandwich and frame stabilized monocoque) were considered for the shell structure of the aeroshell. Both types of construction were analyzed assuming a uniform external pressure on a conical shell which is simply supported at the boundaries. The basic equation for general instability allowable is:

$$P_{cr} = \frac{0.736\ E}{\frac{L}{R}\left(\frac{R}{t}\right)^{5/2}} \qquad [0\text{-}1]$$

where:

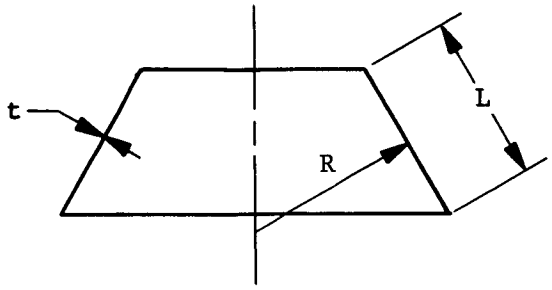
P_{cr} = allowable pressure

E = Young's modulus

L = slant height of the cone

R = average slant radius of the cone

t = cone shell thickness



The two types of construction for the conical shells are idealized to monocoque structures using the assumption that under the discussed loading condition, shell structures having equal radii of gyration in the circumferential direction will work to the same stress level before failing in general instability. Required applicable to the two types of construction considered. These modifications are discussed below.

Sandwich Construction

By equating radii of gyration for monocoque to radii of gyration for sandwich over some finite width, b,

$$\left[\frac{bt_m^3}{12bt_m}\right]^{\frac{1}{2}} = \left[\frac{2bt_f\left(\frac{d}{2}\right)^2}{2bt_f}\right]^{\frac{1}{2}} \qquad [0\text{-}2]$$

where:

t_f = thickness of sandwich face sheet

d = centroidal distance between face sheets

t_m = thickness of monocoque skin

solving for t_m

$$t_m = 1.73\ d \qquad [0\text{-}3]$$

using the assumption of equal stress

$$\frac{PR}{t_m} = \frac{P_s R}{2t_f} \qquad P_s = \frac{2Pt_f}{t_m} \qquad [0\text{-}4]$$

where

P_s = critical collapse pressure for sandwich cone and substituting Equations [0-3] and [0-4] into Equation [0-1], the general ins instability equation for conical sandwich shells is

$$P_s = \frac{3.35Et_f\, d^{3/2}}{LR^{3/2}} \qquad [0\text{-}5]$$

In addition to the general instability discussed above, the face sheet material is checked against yielding. It is also assumed that the sandwich core is of sufficient density and cell size as to preclude face wrinkling and intercellular buckling of the face sheets.

Frame Stabilized Monocoque Construction

The frame stabilized monocoque construction consists of a constant thickness skin stabilized by circumferential frames with zee (or channel) cross sections. The general instability equation for this type of construction is developed in the same manner as for the sandwich construction.

By equating radii of gyration over the same finite width, b,

$$\left[\frac{bt^3}{12bt}\right]^{\frac{1}{2}} = \left[\frac{I}{b_s t}\right]^{\frac{1}{2}} \qquad [0\text{-}6]$$

where

b_s = frame spacing

t = smear thickness of frame and skin

I = moment of inertia of one frame and b_s width of skin about an axis parallel to generator of conical shell.

solving for t

$$t = \left[\frac{12I}{b_s \bar{t}}\right]^{\frac{1}{2}} \qquad [0\text{-}7]$$

using the assumption of equal stress

$$\frac{PR}{t_m} = \frac{P_F R}{\bar{t}} \qquad P_F = \frac{\bar{t}\, P}{t_m} \qquad [0\text{-}8]$$

where

P_F = critical collapse pressure for frame/skin cone, and substituting Equations [0-7] and [0-8] into Equation [0-1], the general instability equation for frame stabilized monocoque conical shells is

$$P_F = \frac{0.736\, E\bar{t}}{LR^{3/2}} \left[\frac{12I}{b_s t}\right]^{3/4} \qquad [0\text{-}9]$$

In addition to the general instability discussed above, various local instability checks must be made for the frame stabilized monocoque structure. As suggested in Reference 4, the various elements of this structure are assumed to be flat plates.

The local instability check for the frame elements, is expressed in general equation form as:

$$P = \frac{K\pi^2 E}{12(1 - \nu^2)} \left(\frac{t_r}{b_r}^2\right)\left(\frac{\bar{t}}{R}\right) \qquad [0\text{-}10]$$

where

K = depends on boundary condition of frame elements

t_r = frame element thickness

b_r = frame element width

ν = poissons ratio

Local instability of the cone skin, between frames, is checked by the use of two equations. Equation [0-11] assumes the skin to be a flat plate and best accounts for the edge restraint for very close frame spacing. Equation [0-12] assumes the skin to be a truncated cone and best accounts for the benefit of hoop continuity for wide frame spacing; therefore, the higher allowable from these two equations is used.

$$P = \frac{K\pi^2 E}{12(1-\nu^2)}\left(\frac{t_s}{b_s}\right)^2\left(\frac{\bar{t}}{R}\right) \qquad [0\text{-}11)$$

$$P = \frac{0.736\ E\ \bar{t}}{b_s}\left(\frac{t_s}{R}\right)^{3/2} \qquad [0\text{-}12]$$

where

t_s = skin thickness

b_s = frame spacing

Analysis consists of selecting appropriate element sizes so that all the stability requirements will be satisfied, the structure will not yield and a minimum weight structure will be achieved.

End Ring

Analysis of the shell structure of the aeroshell assumes the ends of the cone to be simply supported. An end or edge ring is required to provide this support and to prevent general instability of the cone in the N = 2 mode of buckling. Analysis of the end ring was perforemed to establish a ring of minimum mass which is sufficiently stiff to prevent the inextensional form of buckling of the cone shell. Prevention of the inextensional form of buckling allows the design of the cone shell wall and end ring to be uncoupled. The equation which evaluates the end ring stiffness properties is

$$\frac{I_r}{A^B} = \frac{\psi}{C\left(E_r^{\,1-B}\right)} \qquad \text{(Ref 3)} \qquad [0\text{-}13]$$

where

I_r = moment of inertia of end ring about its centroidal axis parallel to generator of conical shell

A = cross-sectional area of end ring

B = generalized stiffness parameter

C = depends on shell properties and ring-eccentricity parameter, (ψ)

E_r = Young's modulus of end ring

ψ = ring eccentricity parameter

Once the cross-sectional shape of the end ring is determined, the end ring moment of inertia and area can be expressed as a function of a characteristic depth and thickness of the specified shape. The characteristic depth and thickness may then be varied, within design constraints, to obtain a minimum mass end ring.

Nose Cap

General stability of the spherical nose cap is checked using an empirical equation from Reference 2. The equation which predicts the nose cap buckling pressure is

$$P = 0.278\ E \left(\frac{t}{R}\right)^2 \qquad [0\text{-}14]$$

where

R = radius of curvature

Application

The aeroshell is analyzed as two conical shells with the payload frame located between. The forward cone is subjected to an external uniform collapsing pressure producing compressive hoop and longitudinal stresses. The aft cone is subjected to an external uniform collapsing pressure producing compressive hoop and longitudinal tensile stresses.

The general instability equation used in this analysis is for structure subjected to an external uniform pressure loading. This is not the case for the aft cone. The stabilizing effect of the longitudinal tensile stresses in the aft cone results in a slightly conservative design, but the general instability equations will be used for both cones.

Analysis of the sandwich structure consists of determining the proper face thickness and core height, for a given cone geometry and design pressure that will achieve a minimum weight structure and satisfy the stability equations and yield requirements.

The general instability allowable of a conical shell is based on the mid-cone geometry of the shell. The general instability allowable of a frame stabilized shell is based on the mid-cone frame spacing and frame geometry. Each element of the mid-cone geometry is checked for local instability. The selected skin thickness and frame geometry at mid-cone is held constant for the entire cone, but the frame spacing is varied forward and aft of the midcone geometry to achieve a minimum weight structure.

III. APPROACHES CONSIDERED FOR PARAMETRIC STUDY

Four basic components (Fig. 0-1) of the aeroshell were considered for the weight study. In the analysis of these components, certain dimensional parameters were restricted in an attempt to ensure a paractical design and a fair comparison of structural weights. A detailed list of the parametric controls is discussed later in this section.

The four aeroshell geometries considered varied only in the base diameter dimension. The four base diameters studied were 2.5, 3.0, 3.5, and 4.0 ft. In all cases, the cone half angle was 60°. The nose cap was assumed to be spherical with a 9.0-in. radius of curvature and a 4.5-in. base radius. The diameter of the payload ring was assumed to be one-half of the cone base diameter. Previous studies have shown that the location of the payload ring has a negligible effect on the cone shell weight. No weight allowance was made in this parametric study for the payload ring.

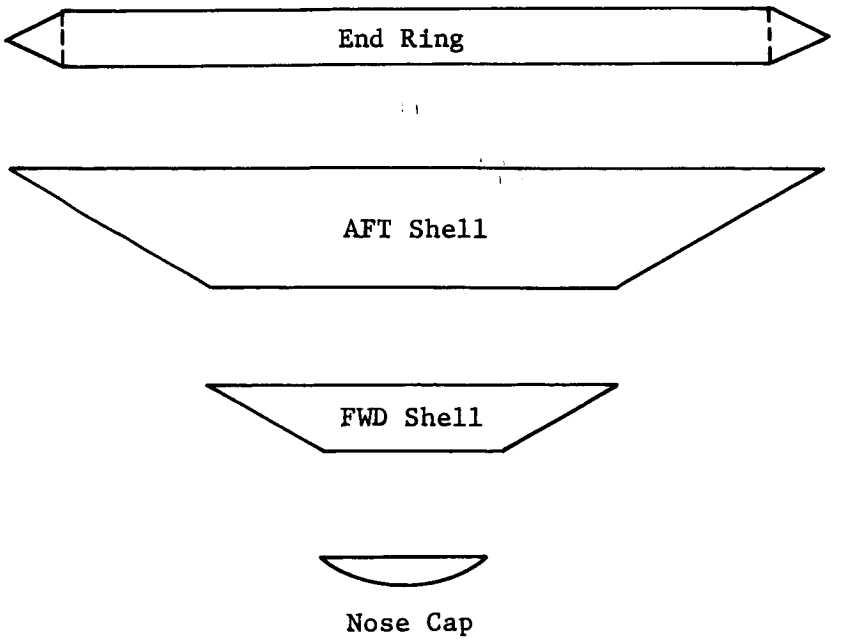


Figure O-1 Aeroshell Components

In the analysis of the aeroshell, only the entry aerodynamic pressures were considered, i.e., a vented aeroshell. The aeroshell weights presented in this study include the cone shell, nose cap, and end ring weights. The aeroshell weights are considered optimum and no allowance was made for difficulty encountered in obtaining the selected dimensions (tolerances) and weight growth caused by fabrication (fasteners, splices, etc.). Sandwich construction includes weights for face sheets, core material, adhesive, and edge members. The weight allowance for edge members was based on each cone being fabricated in quarter sections and each section bounded by an edge member.

The cone shell weights for frame stabilized skin consists of skin and frame weights. The skin is assumed constant thickness for each cone and the frame cross-section geometry is constant for each cone.

The two type of materials considered for this study were 7075-T6 aluminum and 6Aℓ-4V titanium, Cond III. The material properties used were assumed at 200°F and are shown in Table O-1.

Table O-1

7075 -T6 Aluminum	6Aℓ-4V Titanium III
F_{TU} = 71,000 psi	F_{TU} = 143,000 psi
F_{CY} = 63,000 psi	F_{CY} = 135,000 psi
E_C = 10 x 10^6 psi	E_C = 15.7 x 10^6 psi
ρ = 0.101 lb/in.^{3}	ρ = 0.16 lb/in.^{3}

For the sandwich construction, only the face sheet material was varied. The material for the other sandwich components remained constant over the entire range of the parametric study for both face sheet materials. Table O-II lists the sandwich component materials and weights. The end ring material was the same as the selected face sheet material.

Table O-2

Face Sheets	7075-T6 Aluminum or 6Aℓ-4V Titanium
Core, Aluminum	ρ = 0.00470 lb/in.^{3}
Adhesive	ρ = 0.00167 lb/in^2 (two surfaces)
Edge Members, Aluminum	ρ = 0.101 lb/in.^{3}

For the frame-stabilized skin construction, the skin and frames and end ring were of the same material.

The range of design pressures considered was from 50 to 600 psi.

Parametric Controls

In this parametric study, certain dimensional parameters were restricted in an attempt to ensure a practical design configuration. Figure O-2 shows the two types of construction considered and designates the dimensional parameters which were controlled. Table O-III lists the minimum values of these controlled dimensions.

Table O-3

MINIMUM GAGES AND DIMENSIONS

TYPE OF CONSTRUCTION	t_s	t_c	t_r	b_r	b
Sandwich	0.005	0.10	-	-	-
Frame Stabilized Skin	0.020	-	0.015	0.50	0.25

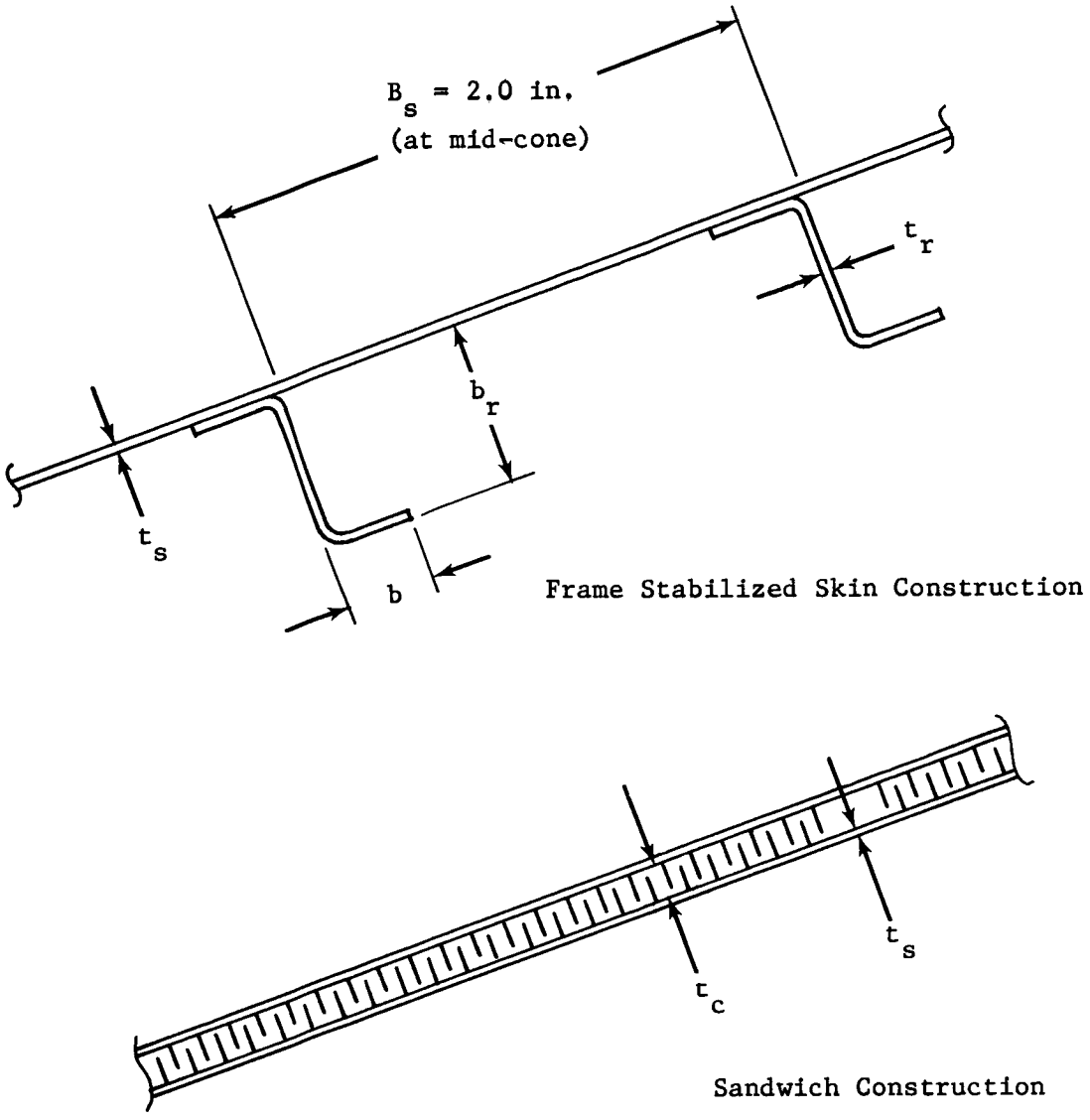


Figure 0-2 Structural Details

Figure 0-3 shows the cross-sectional shape of the end ring and the range of the controlled dimensions which were used for the weighing of the end ring.

IV. RESULTS OF PARAMETRIC STUDY

A detailed weight breakdown for the four basic aeroshell components is shown in Tables 0-4 thru 0-7. The total aeroshell weights are depicted graphically in Figures 0-4 thru 0-7 as a function of design pressures and base diameters. Figures 0-8 thru 0-11 show a comparison of aeroshell weights versus design pressures for the two types of construction and materials considered.

Figures 0-8 thru 0-11 indicate that for the lower range of pressures considered, the aluminum frame-stabilized skin construction produces the lightest weight aeroshell. The titanium frame-stabilized skin construction is relatively inefficient at the lower pressures but becomes more efficient at the higher pressures. The aluminum structure reach a working stress equal to its compressive yield strength at much lower pressures than do the titanium structures; thus aluminum is the more efficient material for either type of construction at the lower pressure range. As the pressure increases and the titanium reaches a working stress equal to its compressive yield strength, then titanium becomes the more efficient of the two materials for both types of construction. The pressures at which the aluminum and titanium curves cross each other is dependent on the base diameter of the aeroshell. (Fig. 0-8 thru 0-11). This cross over point occurs at lower pressures for the larger diameter aeroshell because these shells are more efficient, i.e., for a given design pressure, a larger percentage of the shell structure material is working to its compressive yield strength.

In general, the weight of the sandwich construction was not very competitive with frame-stabilized skin construction at the higher design pressures. When the design stresses of the frame/skin construction are equal to the sandwich face skin stresses, the sandwich construction carries a weight penalty because of the additional components that are not really necessary to carry membrane loads, i.e., adhesive, core, and edge members. At the lower design pressures, when the frame/skin elements are in the instability range, the sandwich face sheets are capable of working to the

compressive yield strength of the material; consequently the sandwich construction weight becomes much more competitive with that of the frame-stabilized skin construction. At very low design pressures (below the 50 psi considered in this study) sandwich construction would prove to be the lighter weight method of construction. This can be seen by extrapolating the curves of Figures)-8 thru 0-11 to design pressures of less than 50 psi.

It is recognized that the total weight of sandwich shell construction is dependent on more variables than that of frame stabilized skin construction. It then follows that the aeroshell weights shown in this study are perhaps more optimum for frame/skin construction than for the sandwich construction. But, in general, for the design pressures, the methods of construction, and types of materials considered in this study, the following summary statements are applicable. Frame-stabilized skin construction results in a more practical method of fabrication and lighter weight aeroshell than sandwich construction. For the lower range of design pressures, an aluminum structure is lighter than titanium but for the higher range of design pressures, a titanium structure will result in the lighter aeroshell structure.

V. DISCUSSION OF USAGE OF CURVES

The curves presented in this appendix provide the basic structural weights for 60° (half angle) conical aeroshells using two methods of construction, two types of materials and a wide range of design pressures. The curves also cover a range of base diameters from 2.5 to 4.0 ft and may be interpolated for base diameters not shown. The aeroshell weights shown represent a nearly optimum weight for the cone shell, nose cap, and end ring. In order to arrive at a complete aeroshell weight, the weights of the payload ring, heat shield, and any other applicable structure should be added to the curve weights shown herein. It should also be noted that the weights shown are considered optimum, it is suggested that a non-optimum factor be applied to these weights to account for material tolerances, splices, fasteners, etc.

It should be emphasized that aeroshell weight curves reflect certain assumptions and constraints which have been previously listed in detail in this section. The curves should be used only as a preliminary guide towards estimating an aeroshell weight. Obviously an accurate aeroshell weight may only be determined after a specific aeroshell design has been established.

VI. REFERENCES

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6. NASA Structural Analysis Manual

Table 0-4 Aeroshell Weights, lb

	FRAME STABILIZED SKIN - BASE DIAMETER = 4.0 ft									
	ALUMINUM					TITANIUM				
PRESSURE	AFT CONE	FWD CONE	NOSE CAP	END RING	TOTAL	AFT CONE	FWD CONE	NOSE CAP	END RING	TOTAL
50	10.6	2.8	0.3	3.0	16.7	14.4	3.9	0.3	5.0	23.6
100	13.5	3.6	0.4	3.7	21.2	18.2	4.9	0.5	5.3	28.8
200	20.3	4.5	0.5	4.9	30.2	23.4	6.1	0.6	6.4	36.5
300	29.2	5.2	0.6	8.3	43.3	27.2	7.0	0.8	7.2	42.2
400	38.3	6.0	0.7	16.5	61.5	33.0	7.7	0.9	8.3	49.9
500	47.3	6.9	0.8	27.6	82.6	40.4	8.3	1.0	11.7	61.4
600	56.3	7.7	0.9	42.0	106.9	47.7	9.1	1.1	18.1	76.0

	SANDWICH - BASE DIAMETER = 4.0 ft									
	ALUMINUM					TITANIUM				
PRESSURE	AFT CONE	FWD CONE	NOSE CAP	END RING	TOTAL	AFT CONE	FWD CONE	NOSE CAP	END RING	TOTAL
50	15.7	2.6	0.3	3.0	21.6	11.9	2.6	0.3	5.0	19.8
100	24.5	3.7	0.4	3.7	32.3	16.7	3.1	0.5	5.3	25.6
200	42.2	6.2	0.5	4.9	53.8	27.2	4.6	0.6	6.4	38.8
300	59.8	8.7	0.6	8.3	77.4	37.7	6.3	0.8	7.2	52.0
400	77.1	11.2	0.7	16.5	105.5	48.2	7.9	0.9	8.3	65.3
500	94.4	13.6	0.8	27.6	136.4	58.6	9.6	1.0	11.7	80.9
600						69.0	11.2	1.1	18.1	99.4

Table 0-5 Aeroshell Weights, lb

	FRAME STABILIZED SKIN - BASE DIAMETER = 3.5 ft									
	ALUMINUM					TITANIUM				
PRESSURE	AFT CONE	FWD CONE	NOSE CAP	END RING	TOTAL	AFT CONE	FWD COND	NOSE CAP	END RING	TITAL
50	7.7	2.0	0.3	2.8	12.8	10.5	2.7	0.3	4.4	17.9
100	9.8	2.5	0.4	2.9	15.6	13.3	3.4	0.5	4.4	21.6
200	13.5	3.2	0.5	4.0	21.2	16.9	4.3	0.6	5.1	26.9
300	19.7	3.6	0.6	4.7	28.6	19.5	4.9	0.8	5.6	30.8
400	25.6	4.1	0.7	8.0	38.4	22.2	5.5	0.9	6.2	34.8
500	31.7	4.6	0.8	13.7	50.8	26.9	5.9	1.0	7.1	40.9
600	37.6	5.1	0.9	20.7	64.3					

	SANDWICH - BASE DIAMETER = 3.5 ft									
	ALUMINUM					TITANIUM				
PRESSURE	AFT CONE	FWD CONE	NOSE CAP	END RING	TOTAL	AFT CONE	FWD CONE	NOSE CAP	END RING	TOTAL
50	9.2	1.8	0.3	2.8	14.1	8.4	1.9	0.3	4.4	15.0
100	14.4	2.5	0.4	2.9	20.2	11.5	2.2	0.5	4.4	18.6
200	24.9	4.2	0.5	4.0	33.6	18.7	3.1	0.6	5.1	27.5
300	35.3	5.9	0.6	4.7	46.5	25.9	4.2	0.8	5.6	36.5
400	45.6	7.5	0.7	8.0	61.8	33.0	5.3	0.9	6.2	45.4
500	55.7	9.2	0.8	13.7	79.4	40.2	6.4	1.0	7.1	54.7
600	65.8	10.9	0.9	20.7	98.3	47.3	7.4	1.1	8.2	64.0

Table 0-6 Aeroshell Weights, lb

	FRAME STABILIZED SKIN - BASE DIAMETER = 3.0 ft									
	ALUMINUM					TITANIUM				
PRESSURE	AFT CONE	FWD CONE	NOSE CAP	END RING	TOTAL	AFT CONE	FWD CONE	NOSE CAP	END RING	TOTAL
50	5.4	1.3	0.3	2.3	9.3	7.4	1.7	0.3	3.7	13.1
100	6.8	1.6	0.4	2.3	11.1	9.3	2.2	0.5	3.7	15.7
200	9.0	2.1	0.5	2.6	14.2	11.7	2.8	0.6	3.7	18.8
300	12.3	2.4	0.6	3.1	18.4	13.4	3.2	0.8	4.2	21.6
400	16.1	2.6	0.7	3.8	23.2	14.9	3.5	0.9	4.5	23.8
500	19.8	2.9	0.8	5.7	29.2	17.0	3.8	1.0	4.8	26.6
600	23.6	3.2	0.9	8.8	36.5	20.1	4.1	1.1	5.5	30.8

	SANDWICH - BASE DIAMETER = 3.0 ft									
	ALUMINUM					TITANIUM				
PRESSURE	AFT CONE	FWD CONE	NOSE CAP	END RING	TOTAL	AFT CONE	FWD CONE	NOSE CAP	END RING	TOTAL
50	6.1	1.2	0.3	2.3	9.9	5.7	1.3	0.3	3.7	11.0
100	9.5	1.6	0.4	2.3	13.8	7.6	1.4	0.5	3.7	13.2
200	16.4	2.6	0.5	2.6	22.1	12.2	1.9	0.6	3.7	18.4
300	23.1	3.7	0.6	3.1	30.5	16.6	2.6	0.8	4.2	24.2
400	29.8	4.8	0.7	3.8	39.1	21.5	3.2	0.9	4.5	30.1
500	36.5	5.8	0.8	5.7	48.8	26.0	3.9	1.0	4.8	35.7
600	43.1	6.9	0.9	8.8	59.7	30.6	4.6	1.1	5.5	41.8

Table 0-7 Aeroshell Weights, lb

	FRAME STABILIZED SKIN - BASE DIAMETER = 2.5 ft									
	ALUMINUM					TITANIUM				
PRESSURE	AFT CONE	FWD CONE	NOSE CAP	END RING	TOTAL	AFT CONE	FWD CONE	NOSE CAP	END RING	TOTAL
50	3.5	0.7	0.3	1.9	6.4	4.8	1.0	0.3	3.1	9.2
100	4.4	0.9	0.4	1.9	7.6	6.1	1.2	0.5	3.1	10.9
200	5.7	1.2	0.5	1.9	9.3	7.6	1.6	0.6	3.1	12.9
300	7.2	1.3	0.6	2.1	11.2	8.7	1.8	0.8	3.1	14.4
400	9.4	1.5	0.7	2.5	14.1	9.6	2.0	0.9	3.1	15.6
500	11.5	1.6	0.8	2.9	16.8	10.5	2.2	1.0	3.4	17.1
600	13.8	1.7	0.9	3.5	19.9	12.0	2.3	1.1	3.7	19.1

	SANDWICH - BASE DIAMETER = 2.5 ft									
	ALUMINUM					TITANIUM				
PRESSURE	AFT CONE	FWD CONE	NOSE CAPQ	END RING	TOTAL	AFT CONE	FWD CONE	NOSE CAP	END RING	TOTAL
50	3.9	0.8	0.3	1.9	6.9	3.7	0.8	0.3	3.1	7.9
100	5.9	0.9	0.4	1.9	9.1	4.8	0.9	0.5	3.1	9.3
200	10.0	1.5	0.5	1.9	13.9	7.4	1.1	0.6	3.1	12.2
300	14.1	2.1	0.6	2.1	18.9	10.2	1.4	0.8	3.1	15.5
400	18.2	2.7	0.7	2.5	24.1	12.9	1.8	0.9	3.1	18.7
500	22.2	3.3	0.8	2.9	29.2	15.7	2.1	1.0	3.4	22.2
600	26.3	4.0	0.9	3.5	34.7	18.4	2.5	1.1	3.7	25.7

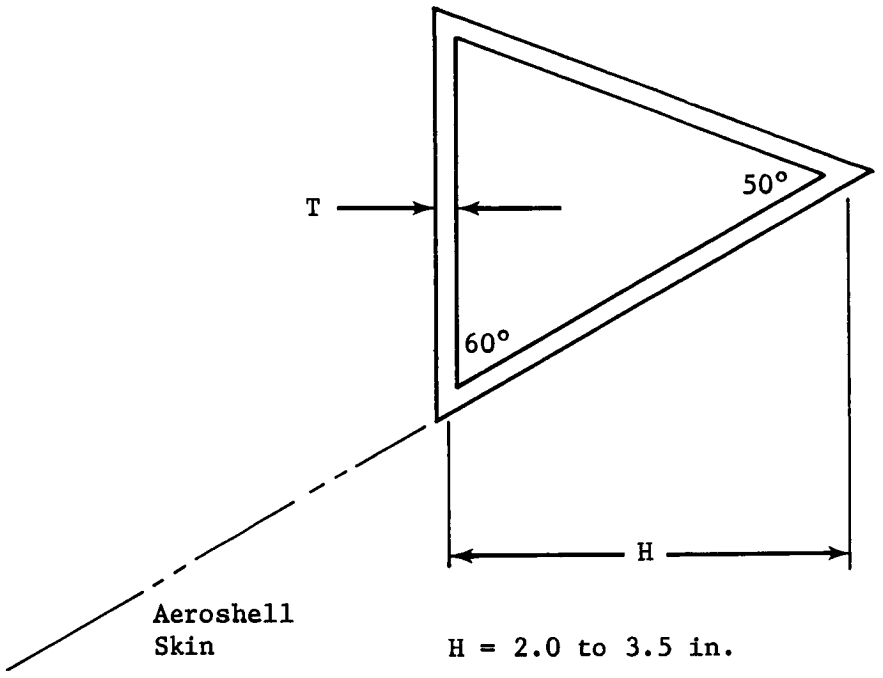

Figure O-3 End Ring Cross Section

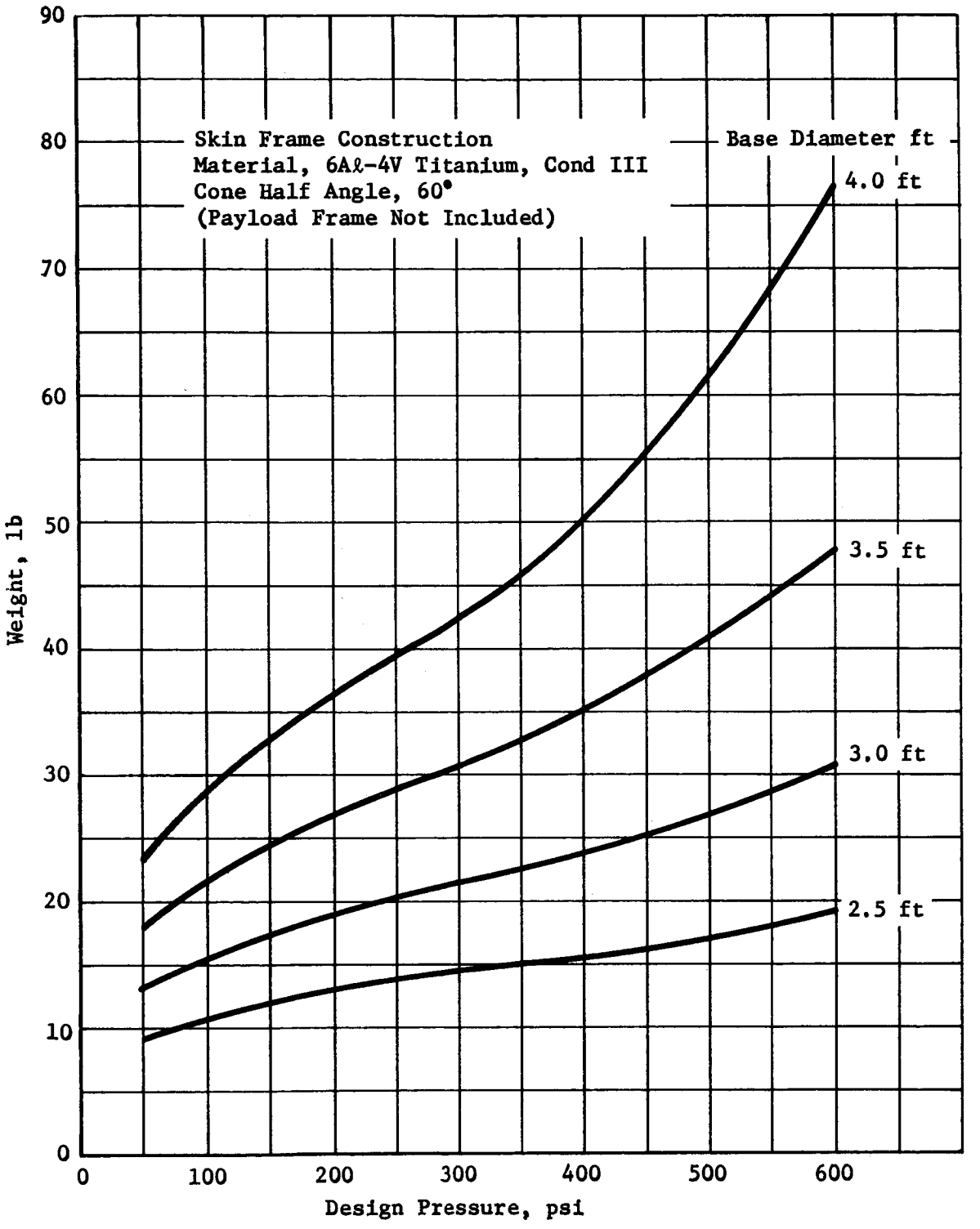

Figure O-4 Aeroshell Weights

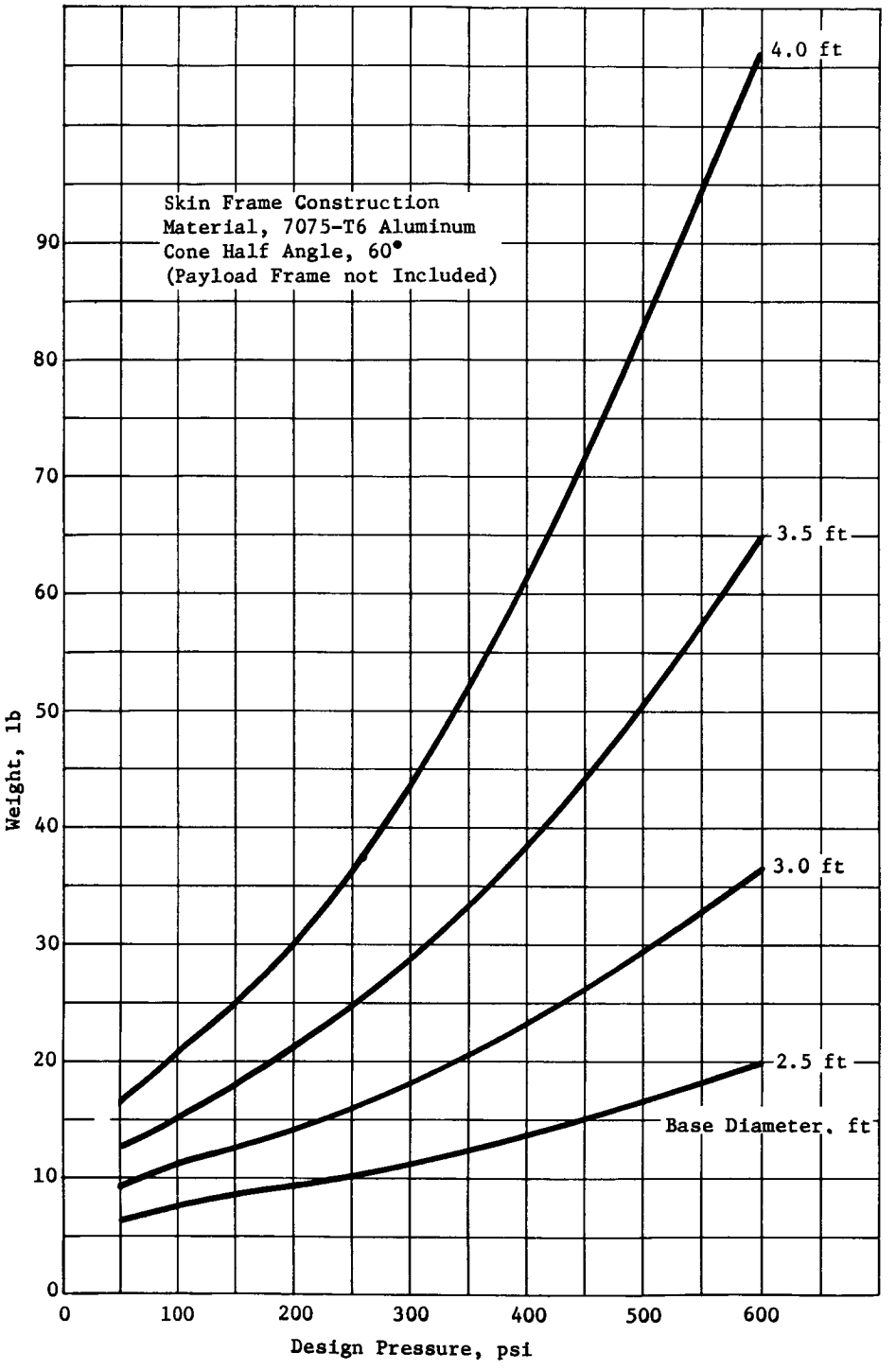

Figure O-5 Aeroshell Weights

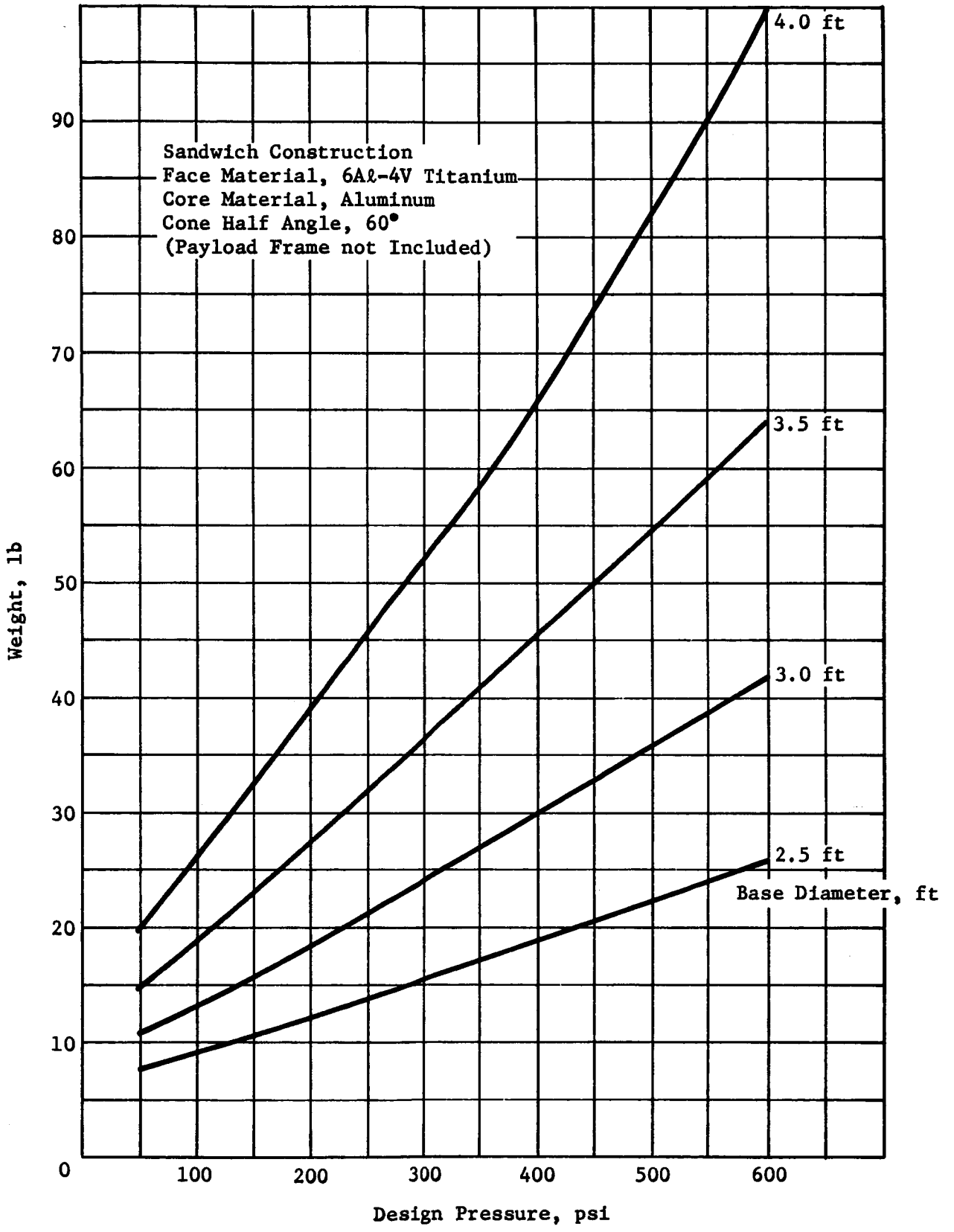

Figure 0-6 Aeroshell Weight

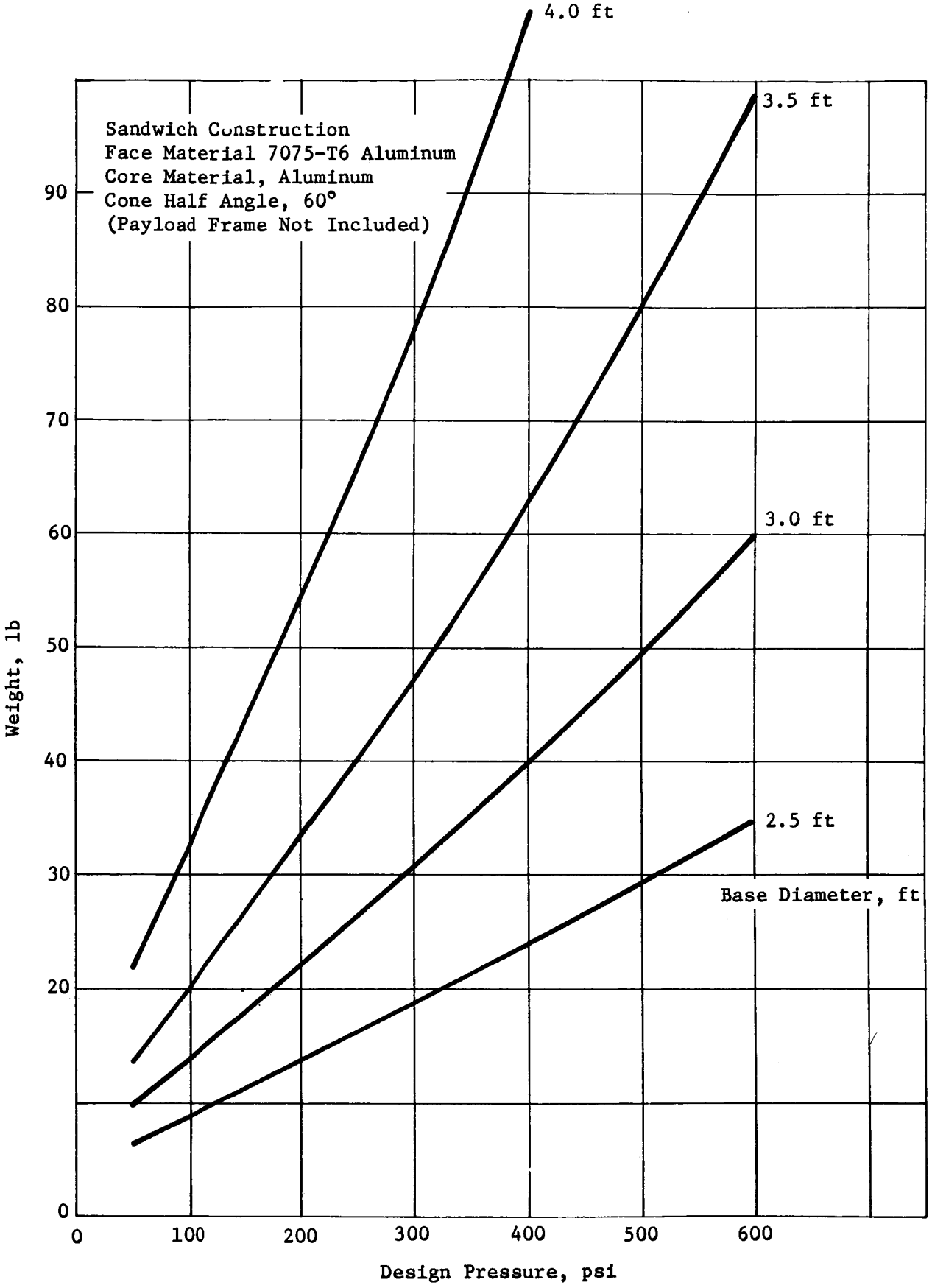

Figure O-7 Aeroshell Weight

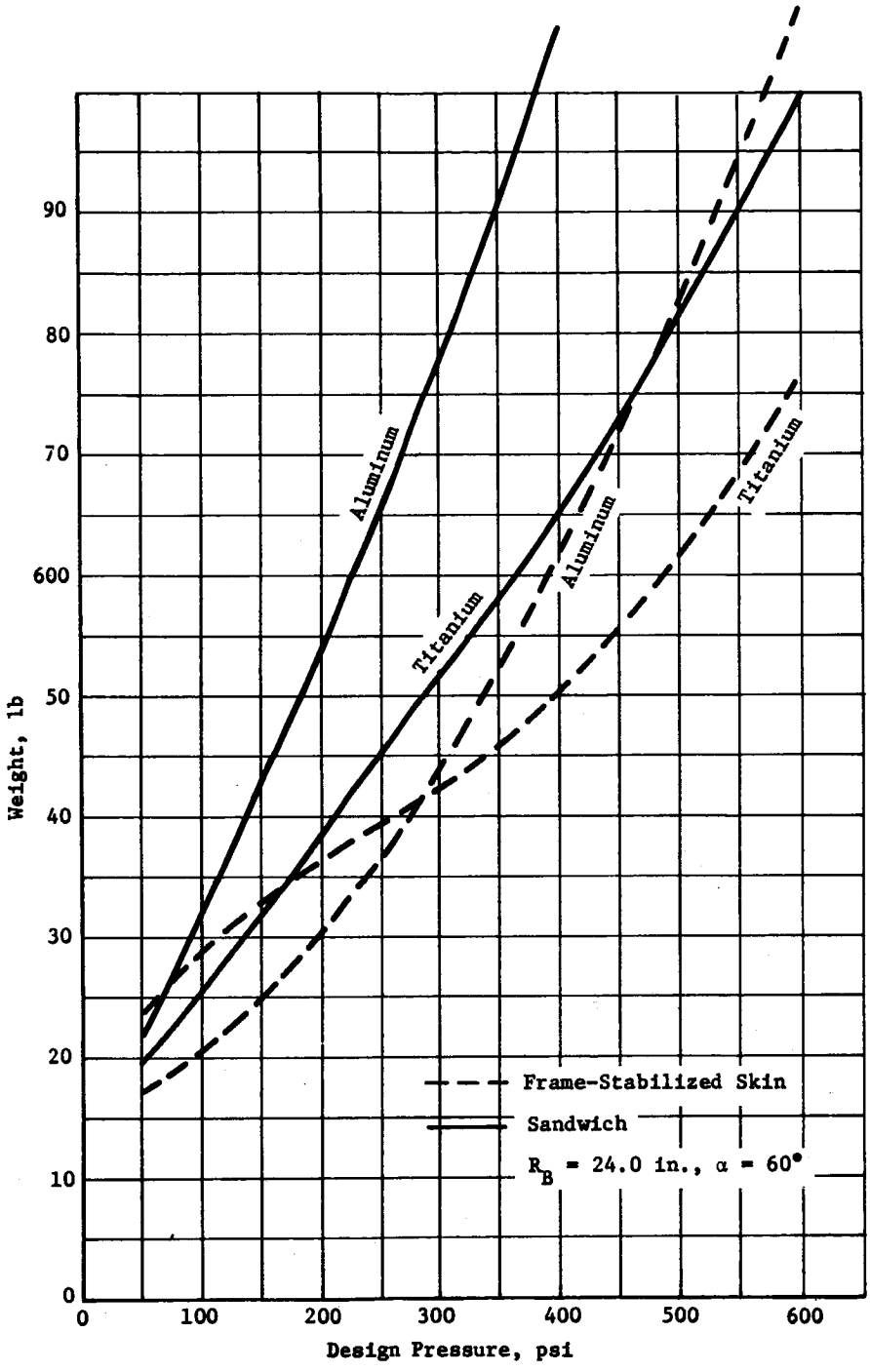

Figure O-8 Aeroshell Weights

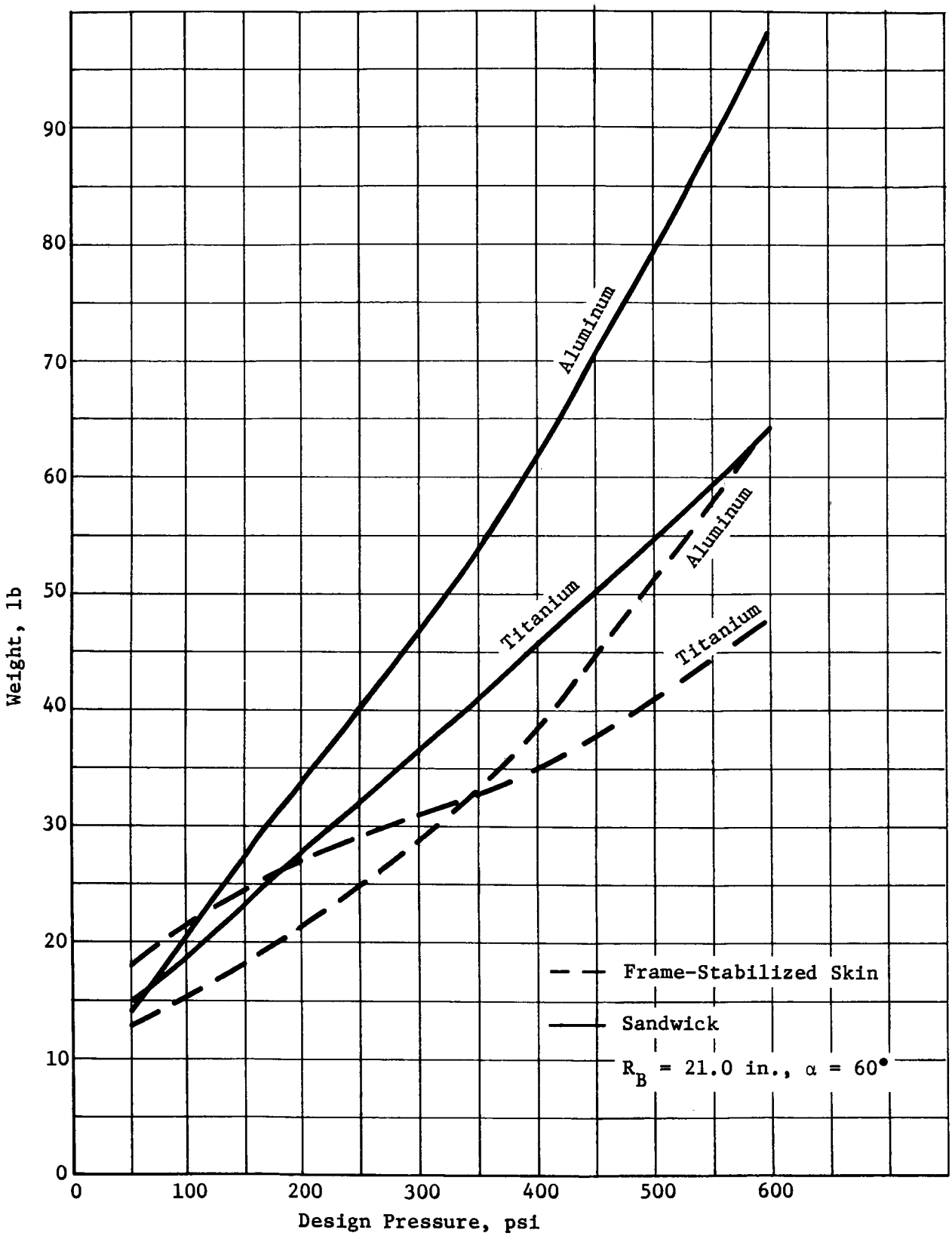

Figure 0-9 Aeroshell Weights

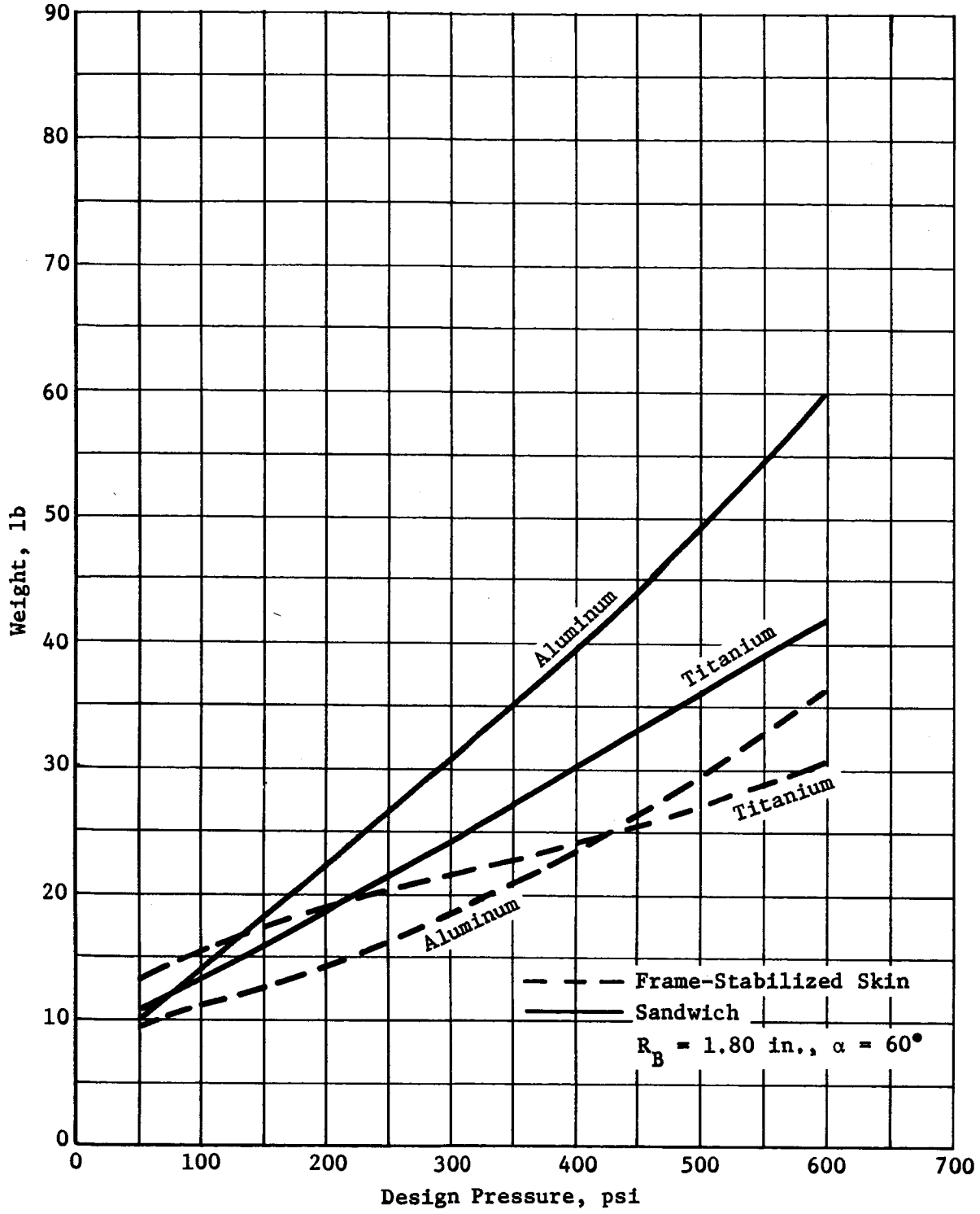

Figure O-10 Aeroshell Weights

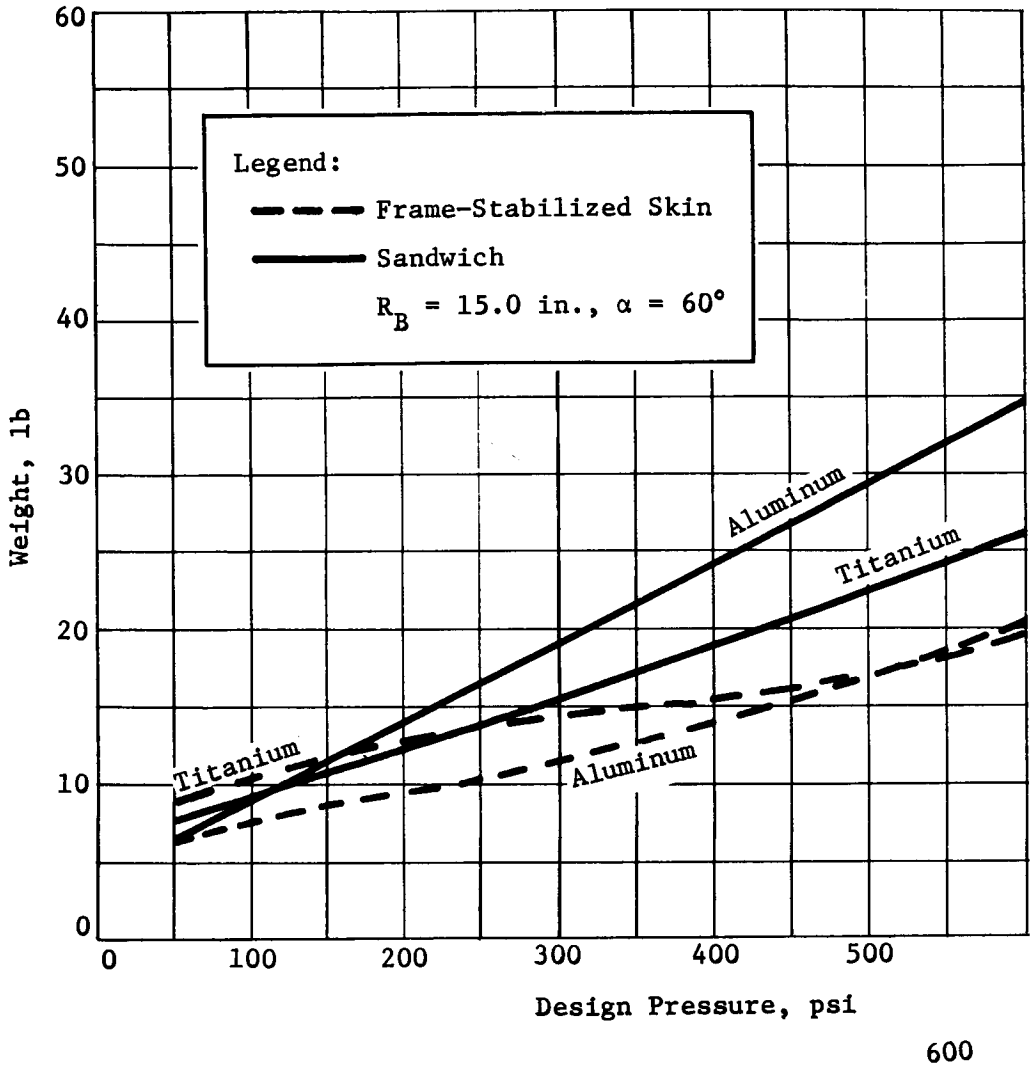

Figure O-11 Aeroshell Weights

APPENDIX P

LIGHTWEIGHT JUPITER PROBE DEFINITION

J. Hungate

June 16, 1972

LIGHTWEIGHT JUPITER PROBE DEFINITION

During the study, the definition of the nominal Jupiter probe had been completed and work on the parametric analyses, identified in Figure V-1, Vol II of this report, was just beginning when a meeting between personnel of JPL and Martin Marietta, indicated that the weight of the nominal Jupiter probe exceeded its expected weight. Therefore, it was agreed that the constraints for the nominal Jupiter probe would be held constant except for those in Table P-1. The effort resulted in the probe configuration shown in Figure P-1 with the corresponding weight breakdown shown in Table P-2. Estimated MMC-MOPS modification is presented in Table P-3. Using a 1350-lb spacecraft weight results in a spacecraft-probe-system weight of approximately 1750 lb.

The probe was defined without knowledge of the entry uncertainty and with only a cursory link analysis which estimated the RF power to be 23 watts at 1 GHz when using a 5-ft diameter spacecraft antenna.

Table P-1 Constraints for Light Weight Probe

MOPS at 1350 lb
T-111 (5-Seg)/Centaur/Burner II
Probe Weight + S/C Modification Weight $\leq$ 400 lb (Goal)
$R_P = 6\ R_J$
Probe Deflection Mode
Deflection Radius = 30×10^6 km (ΔV = 210 m/s)
Entry Angle = 10° (Deceleration Force Reduced From 1500 g to 764 g)
Deceleration to < M = 1 at 100 mb (Entry Ballistic Coefficient = 0.65 slug/ft^2)
Depth of Penetration = 10 bars
Atmosphere - Cool/Dense (Descent Ballistic Coefficient = 0.12 slug/ft^2)

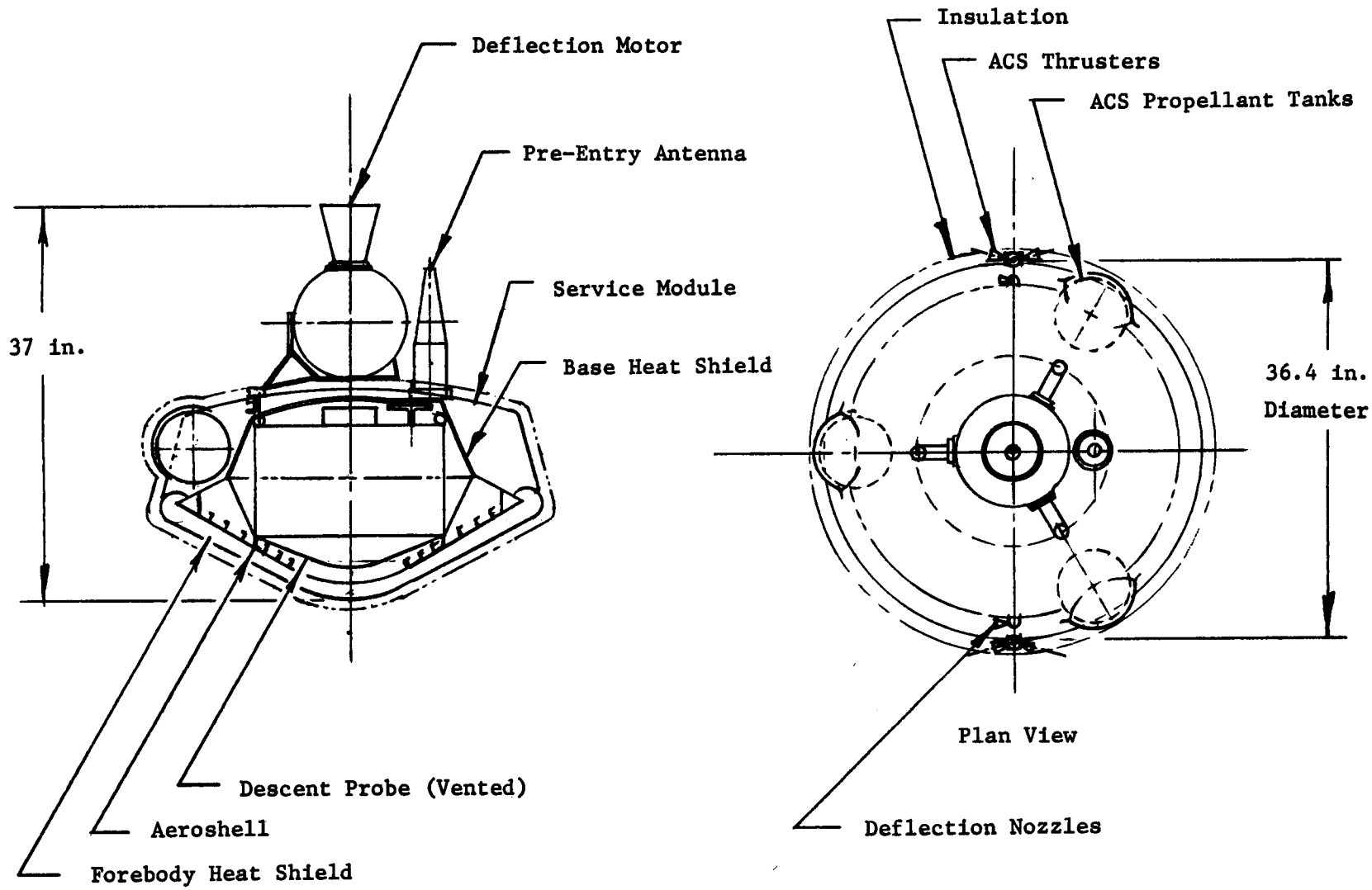

Figure P-1 Light Weight Jupiter Probe Configuration

Table P-2 Weight Breakdown for Lightweight Jupiter Probe

Probe Weight Statement	lb	kg
Science	17.50	7.9
Power and Power Conditioning	10.6	4.8
Cabling	12.50	5.7
Data Handling	5.20	2.4
Attitude Control Subsystem	18.98	8.6
Communications	4.5	2.0
Pyrotechnic Subsystems	11.96	5.4
Structures	59.45	27.0
Forward Heat Shield	62.0	28.2
Mechanisms	12.20	5.5
Thermal	13.70	6.2
Propulsion (Dry)	7.5	3.4
Propellant	27.6	12.5
Engineering Instrumentation	0	0
Margin - (15% of above)	39.50	17.9
Weight Ejected (Total)	303.28	137.5
Weight Ejected	303.28	137.5
Deflection Propellant		
Deflection Propulsion Module & Support (-43.2 lb)		
Nitrogen Gas		
Weight Despun	260.08	118.0
Probe Service Module (-53.41 lb)		
Weight at Entry	206.67	93.7
Ablator Lost During Entry (-45.0 lb)		
Post-Entry Weight	161.67	73.3
Base Cover Quadrants (-22.66 lb)		
Weight on Parachute Initially	139.01	63.0
Entry Probe Body Assembly (-57.5 lb)		
Weight on Parachute Final	81.5	36.9
Main Parachute (-2.80 lb)		
Final Descent Weight	78.5	35.6

Table P-3 MOPS Modification for the 6 R_J Probe

	Lb
Probe Structural Adapter	9.00
Spin Table	20.00
Environmental Cover & Separation	27.20
Receiver Antenna (5-ft diameter)	14.80
Antenna Pointing Drive	5.00
Receiver	2.40
Cabling	2.00
Thermal Control	2.30
Data Handling	0.00
15% Contingency	12.40
	95.10

APPENDIX Q

SEPARATION SPRING ANALYSIS

R. Moses

June 20, 1972

SEPARATION SPRING SYSTEM

It has been shown by analyses and test that a helical compression-spring system is capable of separating spacecraft in orbit satisfactorily, with low tip off rates at separation. This was evaluated for the Air Force Vela satellite and other satellites.* To evaluate the separation of a typical probe from a carrier satellite, the following analysis was performed, using a reference probe weight of 147 kg (325 lbm) and spacecraft weight of 499 kg (1100 lbm). It is shown that the weight of such a system is very nominal.

The total energy imparted to two separating bodies = $E_1 + E_2$ and

$E_1 = 1/2\ M_1V_1^2$ and $E_2 = 1/2\ M_2V_2^2$

where

M_1 = probe mass

M_2 = spacecraft mass

V_1 = probe imparted velocity

V_2 = spacecraft imparted velocity

Total energy then is

$$E_T = 1/2\ M_1V_1^2 + 1/2\ M_2V_2^2 = 1/2\ M_1V_1^2 + 1/2\ M_1 \times \frac{M_2}{M_1}\left(V_1 \times \frac{M_1}{M_2}\right)^2$$

$$E_T = 1/2\ M_1V_1^2 + 1/2\ M_1V_1^2 \times \frac{M_2}{M_1} \times \frac{M_1^2}{M_2^2} = 1/2\ M_1V_1^2 + \frac{M_1}{M_2}\ 1/2\ M_1V_1^2$$

$$E_T = \left(1/2 + \frac{M_1}{2M_2}\right) M_1V_1^2 \quad \text{or} \quad V_1\sqrt{\frac{2E}{M_1\left(1 + \frac{M_1}{M_2}\right)}}$$

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* G. D. Palmer and D. H. Mitchell: "Analysis and Simulation of a High Accuracy Spacecraft Separation System." *Journal of Spacecraft and Rockets*, Vol. 3, No. 4, April 1966.

however,

$$V_2 = V_1 \frac{M_1}{M_2}$$

Therefore,

$$\Delta V = V_1 + V_2 = 1 + \frac{M_1}{M_2} \sqrt{\frac{2E}{M_1 \left(1 + \frac{M_1}{M_2}\right)}}$$

This can also be written:

$$E_T = \frac{\Delta V^2 \, M_1}{2 \left(1 + \frac{M_1}{M_2}\right)}$$

For a separation velocity of 0.91 m/sec (3 ft/sec), the spring energy to separate a 147 kg (325 lbm) probe from a 499 kg (1100 lbm) spacecraft is:

$$E_T = \frac{3^2 \times 325/32.2}{2 \left(1 + \frac{325/32.2}{1100/32.2}\right)} = 35.06 \text{ ft lbf of energy.}$$

For a 3-spring separation system, the energy/spring - 11.7 ft lbf.

It can be shown from spring design tables that spring weight will be in the vicinity of 0.57 kg/Nm (0.017 lbm per ft lbf of energy) for springs having a mean-coil-diameter/wire-diameter ratio of 8 (normal usage). Thus, the springs would each weight 0.09 kg (0.199 lbm). This is an insignificant weight for the separation energy.